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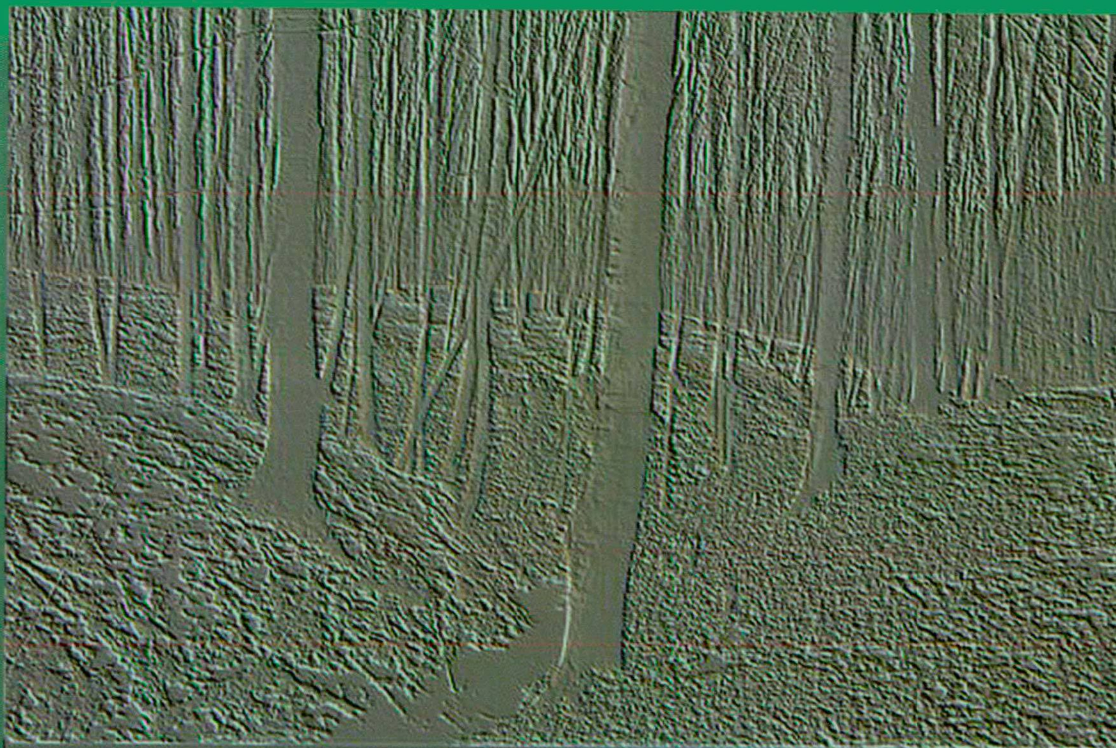
ACTA GEOGRAPHICA

TOMUS XXXVII



SZEGED (HUNGARIA)
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USING DIGITAL ELEVATION MODEL IN GEOMORPHOLOGY IN THE CASE OF THE VELENCE MOUNTAINS

Bódis, Katalin – Csuták, Máté

Introduction

Using sophisticated GIS software makes easier the investigations of geographical processes and offers a new approach to problems. However publications about geomorphologic problems and processes solved by GIS software and database still come out occasionally (*Telbisz, 1999*).

Below are presented some case studies of using digital elevation model in geomorphologic processes. Our primary goal is to prove some part from the landscape evolutional processes presented in the following chapter, therefore we could prove that using GIS methods in morphogenetic investigations is a correct method.

Short summary of landform evolution in the studied area

Several works has already been published about geology and structure of Velence Hills. Explorers of the area, like Vendl (*1911*), Jantsky (*1957*), Vadász (*1960*) agree that the small upland originated from the Palaeozoic, and is a well-defined and fractured remnant of a Caledonian – Hercinian piece of orogen.

After consolidation fractures and splits had dissected the granite on NE-SW direction as a result of different tectonic events. The axis of cracks is parallel with the strike of the hills itself, later cracks and slips developed perpendicularly to this direction, thus orientating the later developed valleys. Traces of Eocene volcanic activity, confined to Upper-Cretaceous orogenic movements in the form, andesite lava can be found in some places mainly on the NE part. Beside of this, remains of Tertiary are Pannonian sediments (sandstone), superimposing directly the basement. Regolith accumulated on the hillslope, deluvial loess and different alluvial sediments form the Quaternary.

Landform evolution and geomorphological feature of the area are described mainly in the essays of Bulla (*1962*) and Ádám (*1988, 1993, Fig. 1*). The small hill dissected to horsts and peneplain under tropical climate during Mesozoic and by Tertiary it had turned into an undulating with low energy of relief (*Bulla, 1962*). Remnants of Eocene volcanism also became removed the prevailing then by erosional processes. Volcanic rocks survived only in the form of necks and secondary volcanic cones. Triggered by tectonic events, related to volcanism, the former consolidated granite segmented into blocks. Subsequently the peneplanisation had continued, which is proofed by the missing Oligocene and Miocene sediments. This process could be the most intensive in the Badenian age. Under subtropical, humid climate, a thick regolith mantle accumulated down to the fresh granite, which had been eroded continuously. This way a slightly undulating secondary peneplain surface. Then, beneath the thick regolith cover, cryptogenetic landforms such as could develop from the isolated fresh granite blocks. At the Sarmatian-Pannonian boundary, the northern part of the hill was dismembered mildly and was transformed into pediment (*Ádám, 1993*). During the Upper Pannonian the whole part of the hills were covered by water. After post Pannonian regression, pedimentation started again. Messinian, upper most stage of Miocene (6.5 – 5 M years ago), might have provided an ideal climate for pedimentation processes. Pannonian sediments were so thick, that it could not be eroded totally from the pediments formed earlier. Therefore in the north, there are covered fossil pediments.

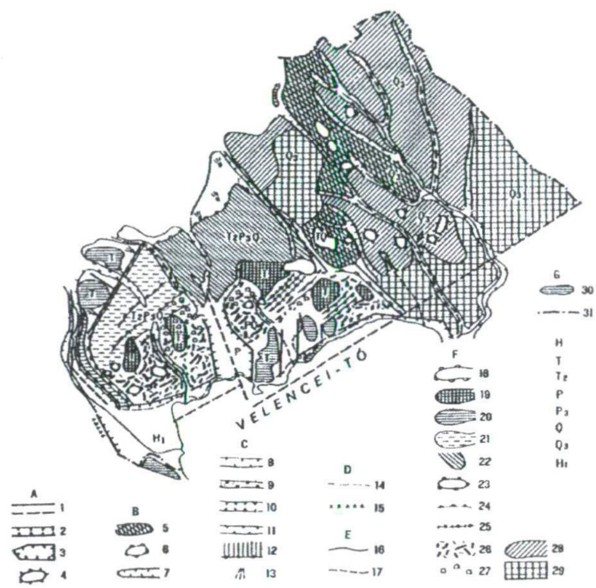

Figure 1 The geomorphological map of the Velence Mountains (by L. ÁDÁM).
A = Exogenous landforms: 1 = fracture line; 2 = trench by faulting; 3 = tectonic basin; 4 = secondary volcanic cone; B = Derasion forms: 5 = derasional ridge of hill; 6 = derasional monadrock; 7 = derasional valley; C = Erosional forms: 8 = erosion valley undifferentiated; 9 = erosion valley with flat floor; 10 = erosion valley with high gradient; 11 = erosional ravine; 12 = New Pleistocene terrace (II a, II b); 13 = debris form of slope washed; D = Lacustric abrasion forms: 14 = primeval shore (showing the highest former level); 15 = fossil abrasional platform; E = Hydrography: 16 = permanent watercourse; 17 = contemporary watercourse; F = Formations with complex genesis: 18 = planated block mountains; 19 = uplifted peneplain remains; 20 = subsided and exhumed peneplain remains; 21 = exhumed fossil pediment surface; 22 = covered fossil pediment surface; 23 = granite monadrock; 24 = eroded stepped vein; 25 = eroded hogback; 26 = eroding peneplain remains under devastation, containing dips without an outlet and hogback, rock pool and monadrocks; 27 = woolsacks, piedestal rocks; 28 = erosional-derasional ridge of hills; 29 = loess plain; G = Antropogen forms: 30 = fishing pond; 31 = boundary of catchment area; H = The age of land forms: T = Tertiary formations undifferentiated; T_2 = Late Tertiary landforms; P = Pliocene landforms undifferentiated; P_3 = Upper Pliocene landforms; H = Early Holocene landforms; Q = Quaternary landforms undifferentiated; Q_3 = Upper Pleistocene landforms; H_1 = Late Holocene landforms

Other types of them are the exhumed, fossil pediments. The rest of the hills is constituted by granite hills at highest positions, uplifted or subsided exhumed remains of peneplaine, denuded steps and special eroded landforms of granite (*Ádám, 1988, 1993*).Ádám (*1988*) showed that there is a difference between the morphology of lesser and intensively beresited granite surfaces. Where corrosion processes degrading rocks, triggered by postmagmatic events, were the most intensive, dome granite backs, denuded ribs and steps of strata granite deposits and pseudokarstic granite plates, developed by biogene granite corrosion, appear. At places where there are quite fresh granite rocks with some biotite and less dykes, exhumed big corestones, sometimes in abundance formed by cryoplanation into breached granite boulder (*Ádám, 1993*). On slopes without loess cover, thick granite rubble has accumulated, felsenmeer formed of them by Pleistocene frost action (*Bulla, 1962*). Erosion of regolith and exhumation of fresh granite blocks have been characteristic processes up to now.

Making Digital Elevation Model

Main and intermediate contour lines have been digitised from topographical maps at of 1:10000 scale of the Velence Mountains. After the required editing and transformation the grid-based Digital Elevation Model (DEM) was interpolated with TOPOGRID module within Arc/Info. The used model-maker algorithm is among the best tools that provide digital terrain model (*Katona, 2000*).

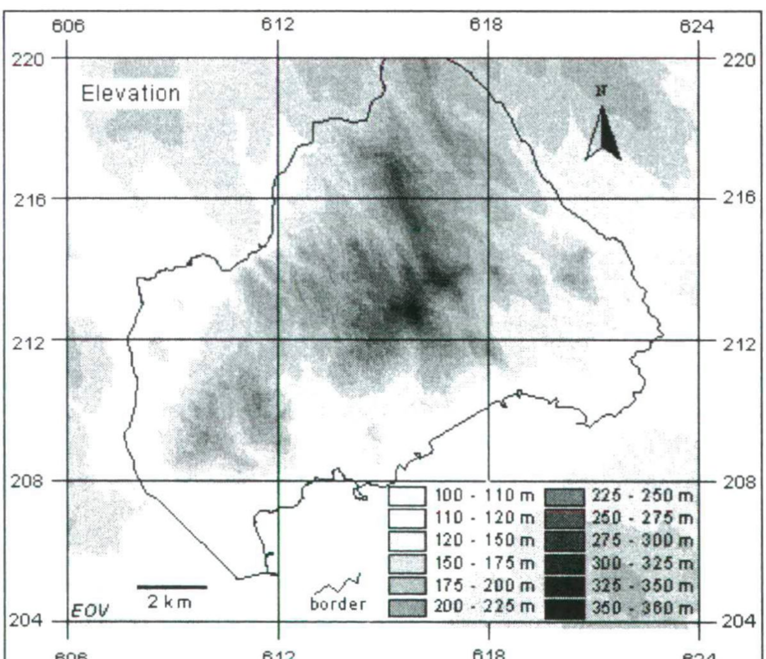

Figure 2 Digital Elevation Model of Velence Mountains

The cell size is 10 m which is a proper resolution in the given scale of the source maps (*Detrekői, 1994*).

Using DEM: the example of Velence-hills

An attempt was made to carry out geomorphological investigations with help of DEM at the following. Of course DEM analyses can only complete and document some parts of results, to be obtained by traditional geomorphological methods and perhaps they are suitable for setting up further direction of the letter. As we will see later DEM methods are usable at first for a purpose of demonstration, in fact they are computer aided and sophisticated variations of geomorphometric methods.

The ready elevation model (*Fig. 2*) could be used well to investigate slope categories, and expositions, energy of relief etc. The main aim of this work, however is not to deepen in different relief assessment investigations, so there is only a reference to it. About categories of slopes (tab. 1) are apparent that gentle slopes are typical of the area. Average energy of relief is lower (64 m/km^2: *Ádám, 1988*)) than that of the Vértes mountains in its neighbourhood. Presumably this is the result of the different geological-petrological structures of the two areas and the more repeated peneplanisation of Velence Hills.

The model is able to make relief profile between two selected points. Earlier Hungarian literature dealt with geomorphological analyses with help of constructed relief profiles (*Kertész, 1974, 1976*).

Angle of slopes	Area (percentage of the total)
0 – 2 degrees	43.1 km^2 (35.5 %)
2 – 5 degrees	38.6 km^2 (31.6 %)
5 – 10 deg.	27.7 km^2 (22.8 %)
Over 10"	12.3 km^2 (10.1 %)

Table 1 Slopes characters at Velence Hills

It has been assumed instead of superimposed profiles used by Kertész (*1976*) we illustrate the profiles one by one. It was practical to make the profiles parallel with the strike (SW-NE, fig. 3/A) and perpendicularly to it (NW-SE, fig. 3/C) with the affliction of the hills and of N-S and W-E direction (fig. 3/B, 3/C). Profiles made by this way allow some basic geomorphological investigations. Gradient of different sides demonstrate quite well that the batolit has tilted to S, SW direction (*Ádám, 1993*), that show the occurrence of steeper slopes tending to this direction. *Figure 3/A* shows well that Lapos valley sectioned SW and NE part of the hills confines to a downcast fault connected to one of the most characteristic fault line. More fractures and faults and presumably erosional valleys along them are discernible on the profiles. Higher features in the NE part (3/A) are former reported granite residual hills and secondary volcanic cones.

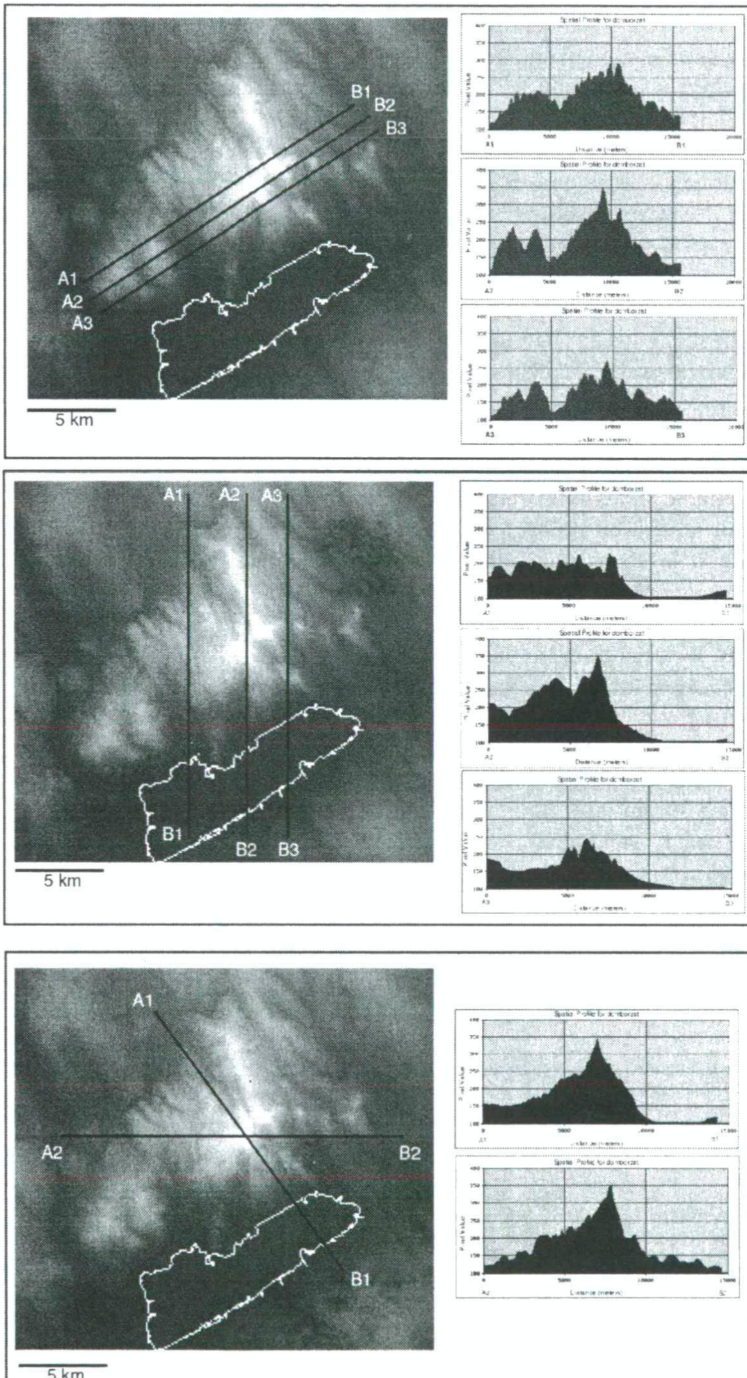

Figure 3 Profiles of the study area

There are not any frequent rises on the SE part. This area is poorer in these landforms, it is mainly exhumed peneplain and pediment (*Ádám 1993*). The break of the gradient on the southern slopes is important. It can be seen on each of the profiles and it may be a previous higher level of Lake Velence. Second profile of *fig. 3/C* shows an eastward link of the hills to Mezőföld plain with steeper slopes. This and first profile of *fig. 3/A* show the different erosion between granite and dykes and in consequence, the morphological and orographic differences. However it should be stressed that these profiles themselves can not proof, they just support the former written facts, reported by the literature.

The Velence-hills must be delineated inside the model for subsequent investigations. Orographical difference between pediments and the plains covered by loess, separated by flows can be recognised. Therefore we postulated that the limits of the hills water courses and bodies (Császár-water, Pátkai-reservoir, Fishlake, Rovákja-creek, Kender-lake, Veréb-Pázmándi-flows, Bágyom-creek, Lake Velence) which their primary catchment area is the Velence-hills itself. The following investigations have been made within the selected area (*fig. 2*) in such a way.

Altitude patterns in the area are shown on *fig. 4*. No exact consequences can be deduced but quite well defined variations of the distribution could show the boundaries of different relief levels. It seems that there are four relief levels in the hills and its area. The lowest of them is about 120-130 meters high. These are accumulation surfaces and belong to the foreland of the hills. It can be seen well on the diagram that these levels are the most spread ones. It does not mean that the separation of the hill and other areas would have been incorrect, because there, the eroded result of the hills accumulates here, and to change the drainage-based limit line of the Velence-hills on the model would not be useful. The next level is about up to 230 m, qualified by Ádám (*1993*) as exhumed or covered fossil pediments. This level can farther be subdivided to a lower and a higher level. By the prevalence of 200-m level of altitude it is assumed be the bounder between the two kinds of pediments, which could have been developed in different ages. From this level, a change in the distribution follows. Columns (*fig. 4*) belonging to higher levels drop approximately in a linear sequence; it may mean another relief part..

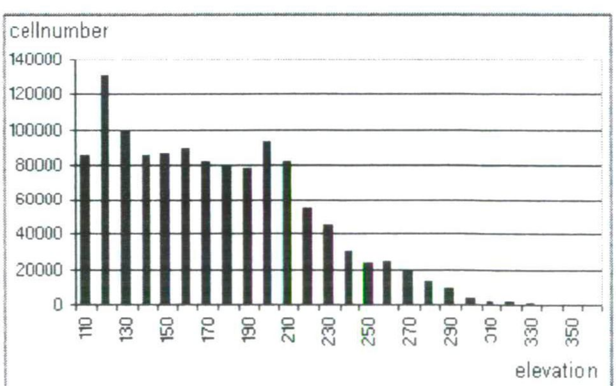

Figure 4 Distribution of the elevation values

It must be mentioned that this 200-m high level does not create a well-defined bounder. Over about 240 m, uplifted peneplains are the characteristic features, this adds the third relief level of the hills. The fourth level composed by the secondary volcanic cones and granite hills uplifted from peneplain. There is a quite great dispersion among the higher position of cones and plains. There are peneplains at higher positions and secondary cones at lower position

Figure 5 shows the map of relief selected by distribution of altitude levels. This shows well the settlements of prepared quartzite dykes, which are more resistant to erosional processes then those of granite.

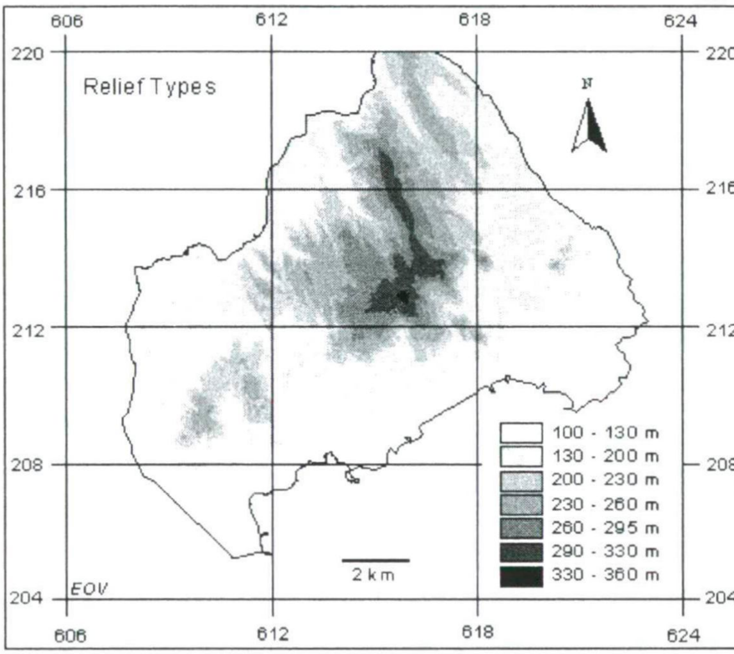

Figure 5 Map of selected relief types

Relief shading is a traditional method to present the surface. During making the screened map for reach parallel lights we presume a basis endless far, that lights our area. For this purpose a source of light is assumed illuminating the area from the infinite. Illuminate surfaces and those being in shadow are function of the angle and trend of slopes exclusively i.e. cast shadows are excluded. A well performed elevation model provides a spectacular and rapid "show" round the hill, after having calculated slope angles and exposures and given the position of the source from of light (azimuth and altitude). Two luminance maps (*fig. 6/A* north-west and *6/B* from north-east) are presented with the mass of the hills the dissected surface of granite and the secondary volcanic cones in the east.

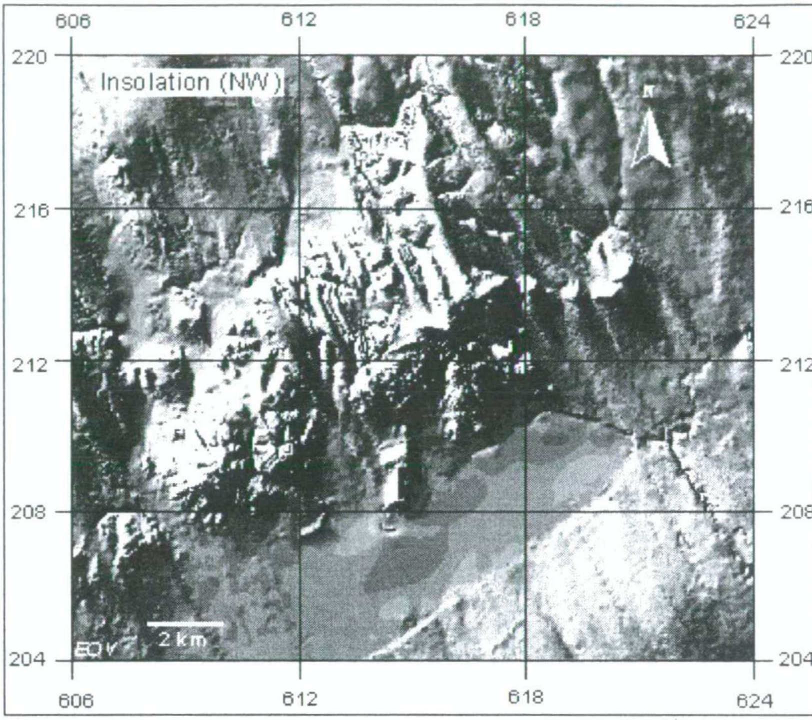

Figure 6/A Luminance-maps of the area (NW)

Conclusion

Among possibilities of using digital elevation models have been mentioned only a few methods. Analyses were made that could help in geomorphologic research. By help of used methods the tilting of batolith, dissection of granite, direction of fractures and valleys along them, were demonstrated. The main surface level of the hills has been selected, and it can be seen well on the map (*fig. 5*) that on the area is mainly occupied by pediments. Secondary volcanic cones and granite hills could be distinguished from peneplains. Orographical differences between granite rocks and dykes are discernible quite well. Luminance maps can be used to observe macroforms and main surfaces of the hills.

Geomorphological investigations using DEM has not ended with this study. The main aim of this publication was to show the capabilities of GIS methods in geomorphologic research.

Abstract

The essay was purposed to show some DEM methods in geomorphological investigations by the example of Velence-hills. Relief profiles, histograms showing the

distribution of altitudes, and the map with the main surface levels on the have proved some details of the geomorphologic evolution history of the area, described by former investigations. Relief screening is suitable to watch the main geomorphological features, valleys and their directions, macroforms etc. These methods presented by this essay give only an idea of the usability of GIS methods.

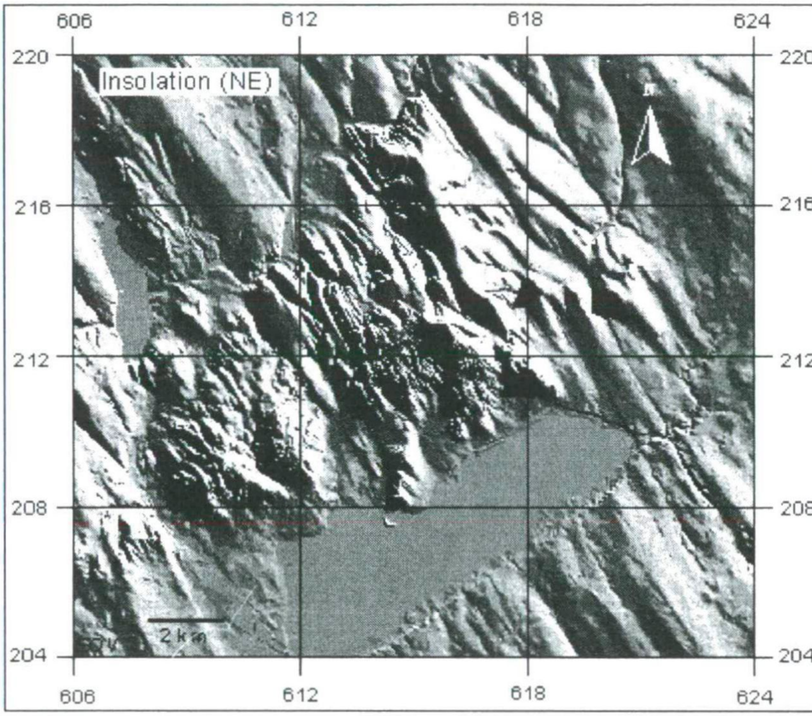

Figure 6/B Luminance-maps of the area (NE)

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LAND USE CHANGES OF THREE DECADES IN THE VELENCE MOUNTAINS, HUNGARY

Bódis, Katalin – Dormány, Gábor

Introduction

62000 km^2 of Hungary's 93000 km^2-area is under agricultural cultivation and it is decreasing continuously since 1990. Now it is smaller with 4000 km^2 than 10 years ago. More than 48000 km^2 are arable land and 17000 km^2 are forest. The vineyard and orchard are 5 % of the cultivated area.[(1)] The ratio of the forest is less than 19 % (the average ratio in the European Union is 40 %). There were two forestations in the country in the 20^{th} century. The first started after World War II and it increased the area of forest with 7000 km^2. Another, similar period started in 1991 and 1.500 km^2 area was planned to be forest until 2000. The pecuniary resources were enough to put through the forestation on the less than half of the planned area, on only 600 km^2[(2)]

Our study area – the first order watershed of the Lake Velence – was a part of these changes and we wanted to investigate the attributes of this transformation.

The Velence Mountains and its surroundings

The Velence Mountains occupies about 80 km^2 in the middle of Hungary with the highest peak Meleg-hegy, which stands 351 meters above sea level. It is a strongly denuded and fragmented Carboniferous granite pluton partly covered with old schist and very young loess. There is a depression on the hillfoot area that contains the 9000-year-old and 1.5-meter-deep Lake Velence with 236 km^2 of watershed area (*Ádám, 1988*).

In the 60's and early 70's, natural values of the area were the lake itself, the relatively intact and hilly landscape and the very temperate climate beside the vicinity of Budapest. It started to be transformed into a strongly used agricultural landscape with cultivation, vineyards and forestry and an increasing rate of weekend and seasonal tourism. The changes of the land use have been severe and easily observable even until nowadays in the 48 - km^2 - broad first order watershed of the lake. It is the southern slope of the Mountains and it takes four villages: Pákozd, Sukoró, Nadap and Velence.

Aims and methods

We were searching for the answers to the next four questions:

[1] Source: Napi Gazdaság, 4. September 2000. Ellentmondásos folyamatok az agrárágazatban

[2] Source: Napi Gazdaság, 4. September 2000. Lassan megtérülő befektetés az erdővásárlás

A) Where did any changes occur?
B) If there were some changes, than from what to what?
C) Are there changes in relation to other physical geographical parameters?
D) Can we recognize any trend in the changes?

We used the tools of Geographical Information Systems (GIS) to compare the land use maps during three time periods, 1968, 1986-87 and 1999.

Sources

The base-maps were the topographical maps in the scale of 1:10000, which set the conditions of the 1986-87 years. The projection system of the maps is the Uniform National Projection System (EOV), a special Hungarian projection. The co-ordinates were given in kilometres. The first order watershed of the Lake Velence is 48 km^2 and 8 maps cover it. The Digital Elevation Model (DEM) was generated from the contour lines and stressed elevation points of the maps. The DEM includes the 4-8 km wide surroundings of the investigated watershed, covering totally the area of the Velence Mountains as well.

We have created the land use map of the 60's using the military maps in the scale of 1:25000, which were published in 1968 in stereographic projection system. The digital version of the soil map is originated from maps containing soil types, subtypes and soil texture categories. The original maps were created for agricultural purposes, so there is not any information about the soils under forests and built-up areas. The map scale was 1:25000.

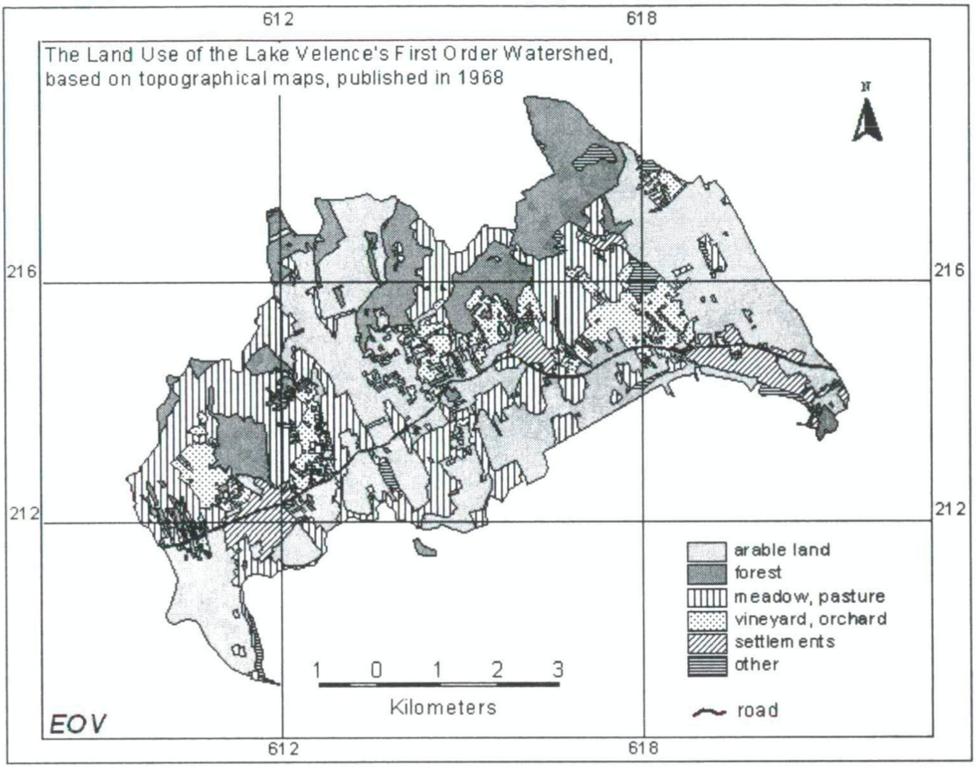
Digital maps

Land use

Based on the topographical- and the military maps we were able to catch the land use changes of the last 32 years for three time periods. The borders of the cultivation were digitized manually from the maps published in 1968 and 1986-87, then the closed areas were labelled according to the categories of the land use. The prepared digital maps were suitable to build polygon topology and to create the land use maps. The characteristics of the land use status in 1999 were mapped during a fieldtrip together with geography students, then this map was also digitized manually. The *Map 1* shows the starting situation in 1968 and the land use from 1999 can be seen on *Map 2*.

The details of the land use categories were different in each case. We could separate vineyards, orchards and vineyards with orchards on the map from 1968 and 1999, while the map from 1986 allowed of the separation into two categories, the vineyards and the orchards. There was no any map that would have contained the type of the arable lands, but we could map this important information during the fieldwork too, so the map from 1999 shows three categories of arable lands. The separation of the cereals, hoed-plants and fodder-plants was interesting because of soil erosion and other hazards. The fact with the forests is similar: there were only two categories separated in 1968, while the other two maps from 1986 and 1999 contained already five types of forests.

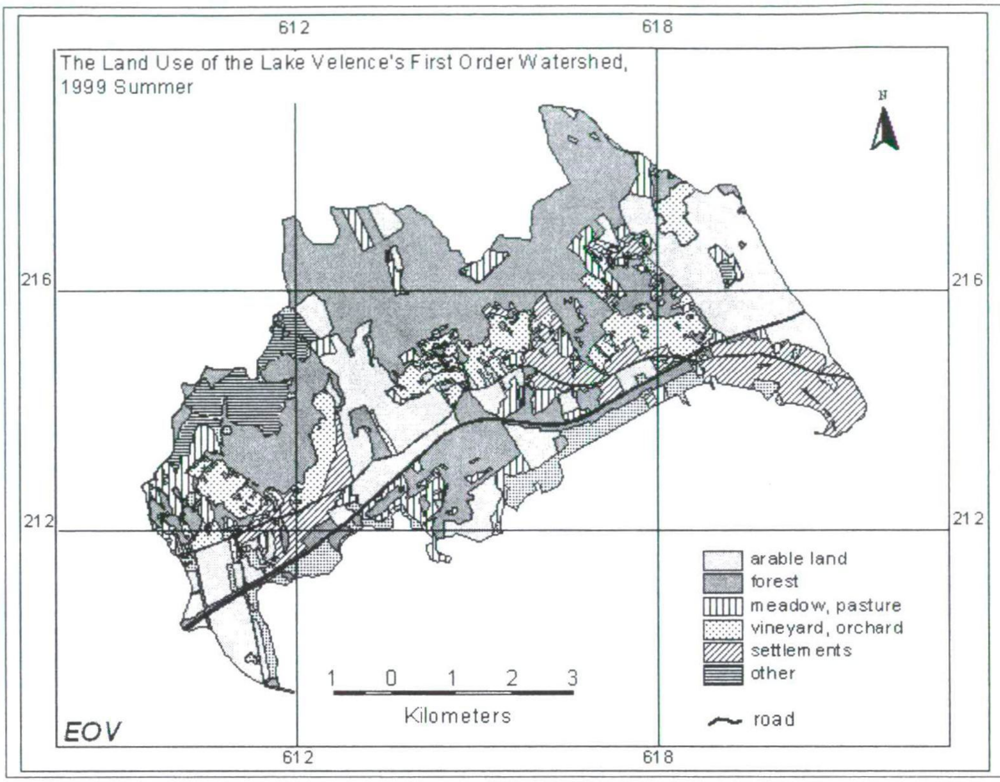
We have used unified categories that were typical of all the three maps to compare the land use from the three time periods. These wider categories were also ordered for the polygons as attribute data.



Map 1 Land use in 1968

Soils

The agricultural soil map in the scale of 1:25000 shows the soils of the mountains and their surroundings, including 5 soil texture categories, 7 soil types and 29 subtypes. We have digitized the patches and rectified them into the EOV system based on control points due to the lack of the co-ordinates on the map. The characteristic codes of the soil patches were stored as attributes, ordered to the polygons. The polygon operators used in the geoinformatical systems allowed us to merge the patches with the same parameters. As a result of this method, we got a clearly arranged digital map, which is easier to use than the original paper map.



Map 2 Land use in 1999

Elevation

We digitized the main and mid contour lines from 12 topographical maps to create the Digital Elevation Model (DEM) for the Velence Mountains. We generated the DEM using algorithm of the TOPOGRID module within Arc/Info. The size of the cell is 10 m. The elevation data of the lakes and reservoirs was replaced by their elevation above the see level. Using these procedures and algorithms of the Arc/Info we have got a hydrologically correct elevation model. We derived the aspects and the slopes (*Table 1*) as the first characteristics of the surface, because we wanted to see the connection between the land use changes and them. The DEM will also be used in our further investigations (soil erosion, landscape household, morphometry).

Steepness	**Area (Ratio of area of the Mountains)**
0 – 2 degrees	43.1 km^2 (35.5 %)
2 – 5 degrees	38.6 km^2 (31.6 %)
5 – 10 degrees	27.7 km^2 (22.8 %)
above 10 degrees	12.3 km^2 (10.1 %)

Table 1 Slope categories of the Velence Mountains

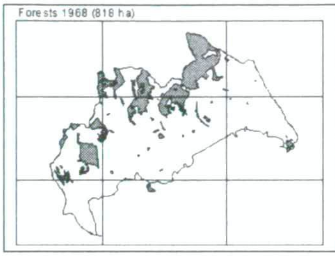
Detection of changes by overlapping

We can follow the structural changes in the land use if we see the aggregated area of the given land use categories between the three time periods *(Table 2)*. We have to take the different origin and scale of the maps into consideration if we analyse the changes. The data of 1968 came from a military map in the scale of 1:25000, the original map of 1986 is the topographical map in the scale of 1:10000 (both were edited by cartographers), while the land use map from 1999 was mapped by geography students during a fieldtrip. For instance, the surrounding area of the villages with gardens, small vineyards and houses were mapped as „built-up area". This generalisation should have taken part in the very strong expansion of the built-up areas in 1999 while the houses and gardens are separated on the other maps.

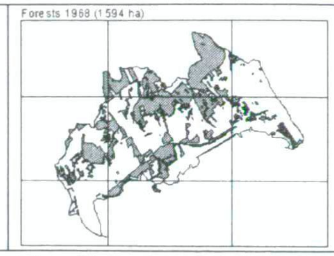
Land use categories	**Total area (ha)**			**Changes (ha)**		
	1968	**1986**	**1999**	**1968-86**	**1986-99**	**1968-99**
built-up area	295.56	353.68	572.52	58.12	218.84	276.96
vineyard, orchard	509.46	430.29	498.90	-79.17	68.61	-10.56
arable land	1963.04	1329.84	1104.58	-633.20	-225.26	-858.46
meadows and pastures	1189.48	504.30	400.69	-685.18	-103.61	-788.79
forests	818.88	1594.65	1845.82	775.77	251.17	1026.94
natural	55.25	474.61	193.18	419.36	-281.43	137.93
wetland	16.68	170.67	208.48	153.99	37.81	191.80
abandoned area	22.50	12.82	46.68	-9.68	33.86	24.18
	4870.85	**4870.85**	**4870.85**	**48,50 %**	**28,42 %**	**51,44 %**

Table 2 The aggregated areas of land use categories and the changes in their area between the three time periods in hectare and the ratio of the total changed area compared to the watershed

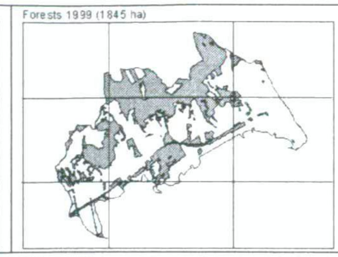
The aggregated area of vineyards and orchards have decreased until the late 80's and increased again after the political changes and the compensation and privatisation of land in the 90's. This increasing has not reached the earlier value yet. The significant decreasing of the total area of meadows and pastures and the increasing of the area covered by natural vegetation should have come from the confused and undefined categories of the maps. For instance, the whole natural vegetation in 1986 was pasture on the western side of the watershed on the map from 1968. The area was for military purposes and it was not permitted to be shown even on a military map. This problem with the categories will be solved, because it is a planned protected area. The growth in the forest area is clear (*Map 3a, 3b, 3c.*). The decline of the area of arable lands and pastures means that the economy became more intensive but most of the „new" fields were turned into forest rather than vineyards or orchards.



Map 3a



Map 3b

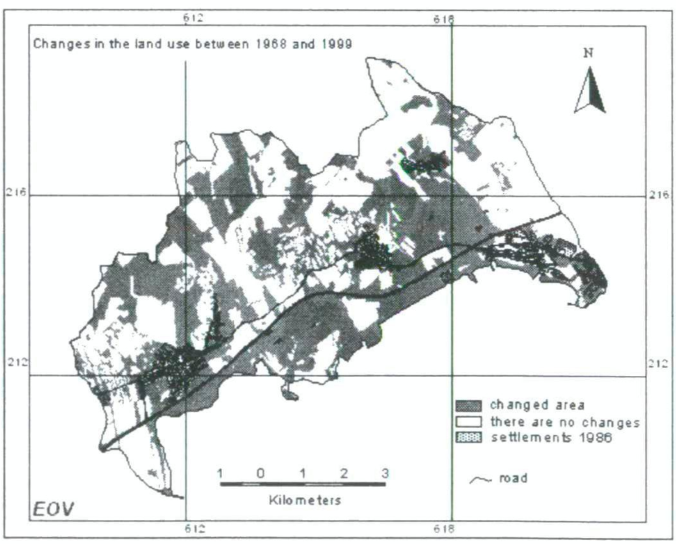


Map 3c

Results

A) Where did any changes occur?

Our analyses are based on grids that we got after the rasterization of polygon maps. The used cell size was 5 m. The cells always inherited the values of the wider, common categories from the polygons. Working with the GIS operations and functions (*GIS by ESRI, 1994*) we were able to identify the changed area and retrieve the changes. *Map 4* shows the changed areas between 1968 and 1999 and *Table 1* contains the ratios of the total changed area compared to the watershed during the three time periods.



Map 4 Changes of the land use between 1968 and 1999

B) *Retrieving the changes*

The investigation of the changed categories was taken by using the exponential function and the place value of the binary system. The algebraic connections of the given values allowed to explore the way of the changes. We have produced a map with using categories of aggregated areas larger than 15 hectares. *Table 3* shows the data used for the map.

1986	1999	Σ Area	Ratio (ws)	Ratio (chd)
arable land	forest	143,2 ha	3,02 %	10,63 %
arable land	vineyard, orchard	109,2 ha	2,30 %	8,10 %
arable land	meadow and pasture	94,69 ha	2 %	2,79 %
Forest	vineyard, orchard	24,4 ha	0,51 %	1,81 %
Forest	arable land	29,2 ha	0,62 %	2,16 %
Forest	meadow and pasture	38,0 ha	0,80 %	2,82 %
Meadow and pasture	vineyard, orchard	34,0 ha	0,71 %	2,52 %
Meadow and pasture	forest	157,8 ha	3,33 %	11,71 %
Meadow and pasture	arable land	45,15 ha	0,95 %	1,33 %
Vineyard, orchard	arable land	17,24 ha	0,36 %	0,5 %
Vineyard, orchard	meadow and pasture	14,88 ha	0,31 %	0,44 %
		707,76 ha	**14.94 %**	**15,88 %**

Table 3 Changes with their aggregated areas and their ratio compared to the watershed (ws) and the total area of changes (chd) (1986 – 1999)

The above mentioned cross-tabulation was completed between the maps from each time period.

C) Are the changes in relation to other physical geographical parameters?

The watershed has a not too intensive relative relief, the changed areas are seemingly independent of elevation and the steepness. The highest and steepest areas were covered by forest earlier and even later. We compared the changed area with the aspect of slopes and the fact was not surprising that most of the changes happened to be on the south-facing slopes, because 65 % of the watershed can be characterized having south-facing slopes and only 11 % with north-facing. Most of the changes took place on sandy loam and loam soils, but the investigated watershed is covered by this kind of soil more than 70 %.

D) Can we recognize any trend in the changes?

Comparing all the changes in our area, we can declare that the forestation was the most significant change during the last 32 years (*Table 2*). The other changes followed the general trends, so the area of the arable lands decreased parallel to the increasing intensity of agriculture. The vineyards and orchards were in decline, but they have been revived since the political changes. The motivation for the changes were pure economical considerations.

Conclusions

Comparing the status of land use in the three above mentioned time periods, we can conclude that the most significant process in the watershed was the afforestation. It happened mainly at the cost of arable lands, meadows and pastures (*Table 2*). The changes in the area of vineyards and orchards are not considerable, but there was some decrease until the end of the 80's.

There was no any physical geographical phenomenon, which one can consider to be responsible for any changes. We suppose that there was only a socio-economical background for the changes. Since the changes have a strong effect on the natural environment we are able to analyse them using the detailed digital land use maps.

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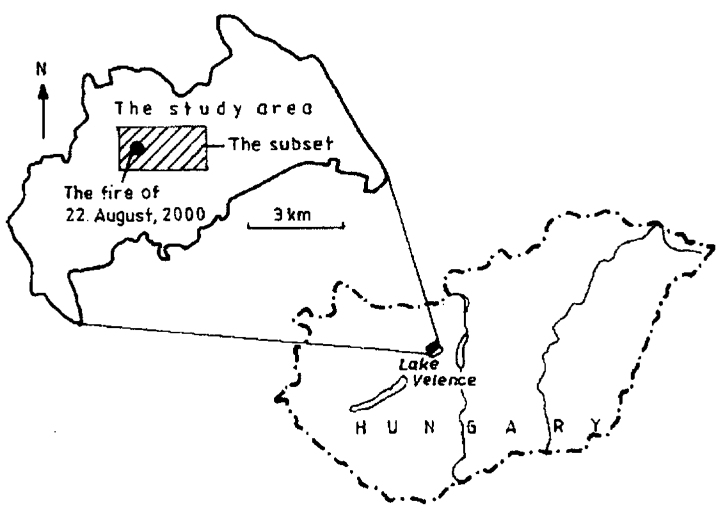
FOREST FIRE IN THE VELENCE MOUNTAINS

Dormány, Gábor

Introduction

On 22nd August 2000, a very quick and devastating fire happened in our test area, the Southern slopes of the Velence Mountains, which is the Northern first order watershed of Lake Velence (*Map 1*). A 25-year-old blank spruce forest burned down seriously in 22 hectares by supposed human irresponsibility. The loss is in millions of forints, not to mention other damage, which is impossible to evaluate.



Map 1 The location of study area

Although Hungary does not belong to the Mediterranean area where 2-3% of total wood area burns down annually (*PIUSSI, 1992*), the phenomena is not unknown owing to the events happening in the last years. The judgement of forest fires is not as obvious as it seems: although it is loss for foresters and menace for firemen to prevent, it helps to renew the ecosystem. The problem with fires is that the damage occurs during a relatively short period of time and causes severe losses in many cases (*SMITH, 1996*) (*Picture 1*).

Forest fire can be interpreted as a geographical problem due to spatial connections of influential factors like weather, topographical or demographical conditions of occurrence, spread and postfire status. It is an important event in the landscape evolution, it can be a cause and a consequence of changes in the land use system, it is a process that connects different entities in time and space. This paper intends to introduce the reader to this issue through references, statistics and analysis of various types of data and facts and tries to draw conclusions.

Picture 1 Landscape after the fire

Method

The risk of forest fire is a combination of structural and dynamic factors. The first branch includes among others the quality and quantity of combustible material, the topography or the cause of fire, which is mainly human and impossible to forecast. The second one contains mainly the meteorological variables like temperature, humidity and others, or the socio-economic factors or the changes in population. Furthermore, the land use, seasonal activities like the combustion of stubble, life around the forest or the power agriculture can become potential causes, sources of fire belonging to both groups.

In the following, I choose some typical factors and try to show how they work in this concept. The different factors demanded different approaches to investigate from analyses in GIS to statistics, as they are members of an existing fire risk mapping and modelling method (*Natural Hazards Project, 1999*).

What is risk?

First of all, it is important to clarify some expressions. Forest fire or wildfire or wildland fire – different words can be used in parallel – is a *hazard*, as normal as other processes in nature like landslides, earthquakes or tsunamis. The probability of its occurring, the loss caused by it and the vulnerability of the objects create its *risk*, and make fire risky on different rates. To put it simply:

$$\textbf{risk} = \textbf{probability} \times \textbf{vulnerability} \times \textbf{loss.}$$

This definition of risk is only one of many but I consider it the best approach and find it detailed enough. For a general and theoretical instance, standing under a chestnut tree in autumn is highly risky due to the frequent fall of chestnuts and the possible wound on the head, which can cause a two-week-long sick-leave after the hit. On the other hand, running in a flowery meadow and wearing a helmet in springtime is an effective way of mitigating this risk.

Researches on forest fire

Fires in general and moreover fires in wood are in the focus of various researches from different approaches. PERRY's article is a detailed overview of the modelling and the ways of methods (*1998*). The remote sensing started to be used in researches on fires decades ago, and nowadays it is also current for studying. The classification of the vegetation for mapping fire hazard is successful (*ANTONINETTI ET AL, 1993, EL GHAZZAWI, 2000*), the evaluation of damage after events is also easier using remote sensed data (*GUTMAN ET AL, 1995*). To handle effectively the data of this complex process and analyse it precisely would be too much time-consuming without information systems. CHOU's work is also persuasive in management (1992), and although GIS is a versatile instrument, it can be completed with special modules like the PRINCE (*BACHMANN, 1998*). Using remote sensed data and GIS together is the most fruitful considering accuracy and its multifaceted character (it is widely used from prevention to modelling) (*CHUVIECO ET AL, 1989, KUNTZ ET AL, 1993*).

On the other hand, effects on the ecosystem (*KNIGHT, 1987*), the sensitivity of a landscape to this threat (*VAZQUEZ, 1993*) or the postfire mechanisms (*REGO, 1992*) and forest responses (*GILLON ET AL, 1992*) were also studied in details.

Of course, in this chapter I only tried to pick some of the millions of studies, it would be worth introducing all in another paper.

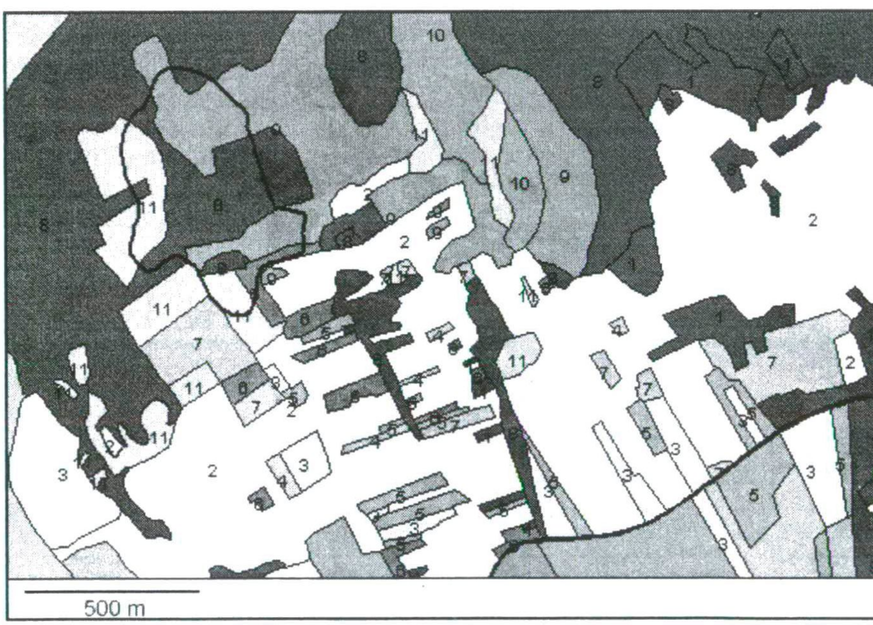
Land use changes in the Velence Mountains

The land use is spatial projection of human activity in a given moment. It appears as patches and covers totally the surface with different types of categories. Our maps of three years - 1968, 1986 and 1999 - representing the changes of the last 32 years were derived from topographical maps in the scale of 1:10000 and partly from field mapping. The southern slope of Velence Mountains covering 48 km^2 is the northern first order watershed of Lake

Velence, and different land use types occupy it: settlements and built-up areas, vineyards and orchards, forest, arable lands and pastures are the main ones. The maps were digitized, overlapped and analysed using GIS like ARC/INFO and ArcView, and the following facts were found:

- the area of the arable land area has decreased which is similar to the national economic changes,
- most of the changes were from arable land and pastures to forests, so the afforestation is significant (more than 1000 hectares only between 1968 and 1999),
- the area of vineyard has increased in the 90's after severe decreasing in the 70's and 80's (*BÓDIS ET AL, 2000*).

In our case, the readable change is the growth of forested area that is understandable regarding the geological and pedological conditions; thin and highly erodable soil layer covers the acidic granite and schist rock formation.



Map 2 The land use map of the study area, 1999 (the map is only a subset of the whole study area)
The numbers represent the following: **1**: settlements, built-up areas, **2**: vineyards and orchards, **3-5**: arable lands, **6:** abandoned areas, 7: meadows and pastures, **8-12**: forests

Parallel to this growth, the area of the possible burning has also increased. The source of ignition and the combusting fuel are linked to the land use too. In our case, most of the forest are contiguous to settlements which is a constant risk of human cause in ignition due to tourism, children's play or arson. Neighbouring arable lands are a threat too; permanent working in 9 months with machines or burning of stubble in autumn can cause fire in forests. Human activity is the main cause of ignition as fire history proves. Fuel type is a structural factor, it depends on the type of the timber and the undergrowth and the activities of forestry like plantation and cutting, etc.

The most threatened forests are the blank spruces in Hungary, partway owing to the dry pine needles and mostly the high resin content, and they represent nearly half of the about 1800-hectare-big forest in our study area (*Map 2*). Proximity to roads has a two-folded importance: their intensive use increases the risk of ignition by letting everyone reach the woods and on the other hand, they can hinder the spread of fire and help to approach the burning parts (*MEZŐSI ET AL, 1998*).

Meteorological variables

The meteorological variables are dynamic factors and easily usable to tell anything about the fire risk rate. The temperature, the precipitation and humidity are as important in the origin as wind speed and directions are in the spread of fire. One of the methods to estimate the possibility of fire due to weather conditions is computing fire risk indices like the Angström Fire Risk Index from Sweden that is precise and calculable enough to apply. The Index can be calculated from the following formula:

$$B = 3{,}3 - 5f + \frac{T}{10}$$

where f is the relative humidity at 2 p.m. and T is the temperature at the same time (*BUSSAY, 1995*). The results can be divided into five different categories:

≥1.5: ***Negligible*** **1.5-2.5:** ***Little*** **2.5-3.5:** ***Average*** **3.5-4.5:** ***High*** **4.5≤:** ***Extreme***

Using the meteorological database of the Plant Health and Soil Conservation Station in Fejér County, Velence, I could count this index for the period between 1st April and 20th September. The period was extremely dry: the amount of precipitation was only 201 mm during the 29 rainy days, which is less than the half of the normal. The values of temperature broke records most of the days, the mean temperature was over 25°C, the maximum values were permanently over 30°C and in the middle of the summer over 40°C! Owing to these extremities, not only the forest, but the whole area dried out, the water of Lake Velence decreased to a scary low level.

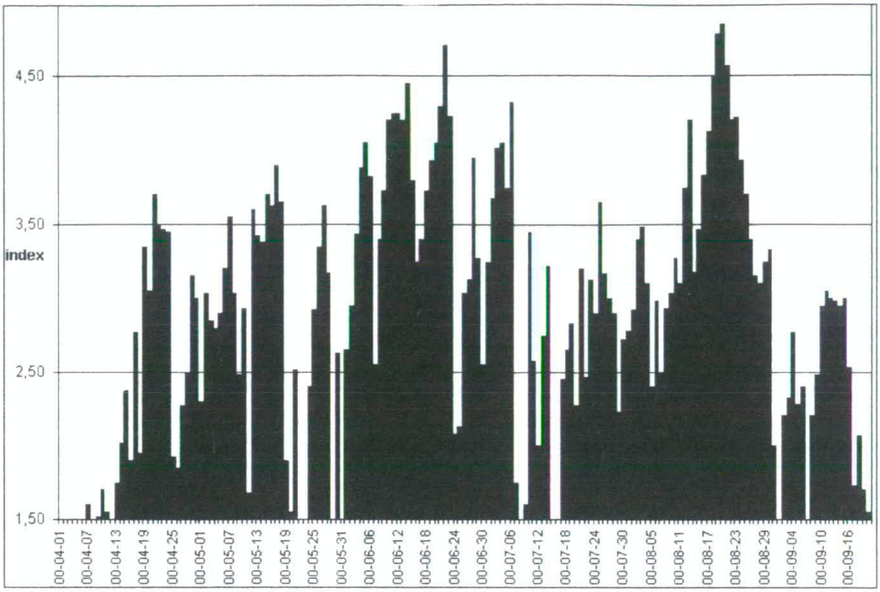


Figure 1 The Angström Fire Risk Index between 1st April and 20th September

The value of the Angström Fire Risk Index reached the 3.5 of high category on 38 days (of 174) and the 4.5 of extreme on 5 days which means that the quarter of this period was fire risky. June was particularly risky: almost the whole month proceeded in this condition, similarly until the middle of August (*Fig. 1*). As it is seen, three days before the fire the value went over the lower limit of extreme category after staying 3 more days in the high category. Unfortunately, there is no space here to deal with the wind that can strengthen the spread of fire and partly depends on topography.

Fire history

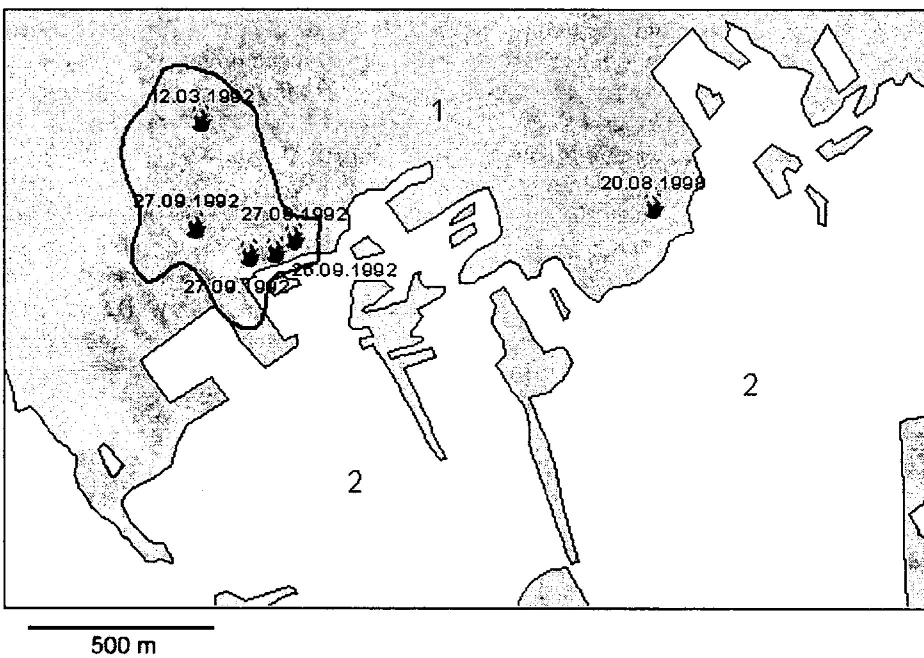
Setting up the fire history is a very useful statistical method to help to evaluate the combustion risk of a given geographical unit with the proper data of former events (*VAZQUEZ ET AL, 1993*). It is possible to map applying GIS if we have the coverage of the single events (*CHOU, 1992*). It makes possible to establish risky periods of time, dangerous places and the most usual causes which are mainly human: accidental or intentional. It is an enormous help in preventing fires and preparing for further actions or managing fighting in dangerous situations.

Using the database of the local Fejér County's Department of Fire, we have a proper image of the area's fire history. The table includes parameters of fire-events in the last 10 years like date, place, area, cause of fire, etc. (*Table 1*).

Date	*Location*	*Cause*	*Occupation (m^2)*
91.04.02	Pákozd - 37/A forest scene	unknown	100-1,000
93.05.30	Velence - around the waste deposit	open fire	> 100,000

Table 1 Example from the used database

I have put the single events on the map of land use and found that the patch of the fire of 22nd August suffered many times earlier (*Map 3*). This fact increases the probability of ignition due to the tendency. On the other hand, it may decrease the loss because of the burned down fuel.



Map 3 The map of fire history (a subset of our study area)

The thick black line shows the shape of the forest which burned down on 22nd August 2000. The dates represent the earlier events, the numbers stand for: **1:** forests, **2:** other than forests

Effects of fire

The fire causes huge loss as the price of the combusted wood can easily reach millions of Hungarian forints. Disappearing of timber is a problem itself in a country where less than 20% of the area is forested. The ecosystem's damage, taken from the passing away of plants in macro- and micro-scale to the appearance of new and strange, mainly weed species and wattle, causes severe degradation. In our case and from the tourism's point of view, fire events do not raise the visitors' sense of safety, and this fact might lead to the drop of income in a region where it is a strong source of livelihood. The disappearing of one capital appeal, the value of nature beside clean air and silence could worsen this fall.

A special and many times modelled problem is soil erosion after fire due to the loss of foliage and leaves that has long-term effects. Field measurements and observations have shown that the annual soil erosion after a severe fire can be fifty times more than before (*GIOVANNINI ET AL, 1992*). Even if the weather conditions are unfavourable regarding soil erosion, the precipitation slowly affects the upper layer and starts to transport it away, and this process is hardly stoppable. It is definitely true in our case too, owing to the geological and pedological situation, since the granite pluton is covered with its weathered small particles and it is highly denuded at some places opening up the rocks forming boxes and the so called "wool sacks". The layer of soil is shallow, less than 10cm in average, so it is not accidental to meet forests on the severe part of the pluton. They were deliberately planted and it is similar to the country trend; the half of the 770.000 hectares of skeleton soils is covered by wood (*SZODFRIDT, 1996*). It is enough for the trees to live on and protect the soils until the forest is cut or burned down. In the latter case, advantageous things happen for instance the possible increase in global P by deposition of ashes (*FERRAN ET AL, 1992*), but this ash-layer can be washed off easily especially by the first rainfall event (*FERREIRA ET AL, 2000*). It is absolutely sure that the following facts are disadvantageous like the 90% of humus layer can be burned up in a severe fire according to PIETIKÄINEN and HANNU (*1992*) and the loss of N could be extremely high a year after the event (*SERRASOLSAS ET AL, 1992*). In cases like in the Arbucies basin, the sediment loss after fire could be 13 times higher than in pre-fire conditions (*ROVIRA ET AL, 2000*), the loss of the total nutrients can be 3-4 time more than before the fire (*THOMAS ET AL, 1999*). Besides, it is not so simple to answer the question how the area's heat and radiation, and of course, the water balance change.

Conclusions

The soil loss in our test area is being evaluated by different investigations from the application and validation of the EUROSEM model to field measurements. To state more precise parameters of this process, we started to measure the amount of the eroded sediment and its qualities. It is based on the collection of soil in modified Gerlach-type sediment traps on three slopes that have the same length of 10 meters and gradient of 5-6° (10-12%). One of them is under trees untouched by the fire, the second is under a partly, the third one is under a totally burned timber. We suppose that the eroded soils' quality increases to a several-times-higher level and the amount of different nutrients in the upper layer will change. Considering that the whole study area is the first order watershed of the environmentally very sensitive Lake Velence, the changes in the watershed will indicate changes in the lake, from the quality and quantity of water to the ecosystem in and around the lake.

As it was mentioned above, many approaches exist to model fires and some of them are worth trying. In the future, I want to try out some of them and compare their efficiency, accuracy, suitability to manage this risk. By this investigation, I will try to find proofs for the theory that the land use has influence on natural hazards' risk and risks affect the use of the land. At last, I will try to create a model to involve this theory and I would try to use it in distinct cases and study areas.

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SOME STRATIGRAPHIC PROBLEMS OF 'MASTODON GRAVELS' IN THE HUNGARIAN GEOLOGICAL LITERATURE

Burján, Balázs

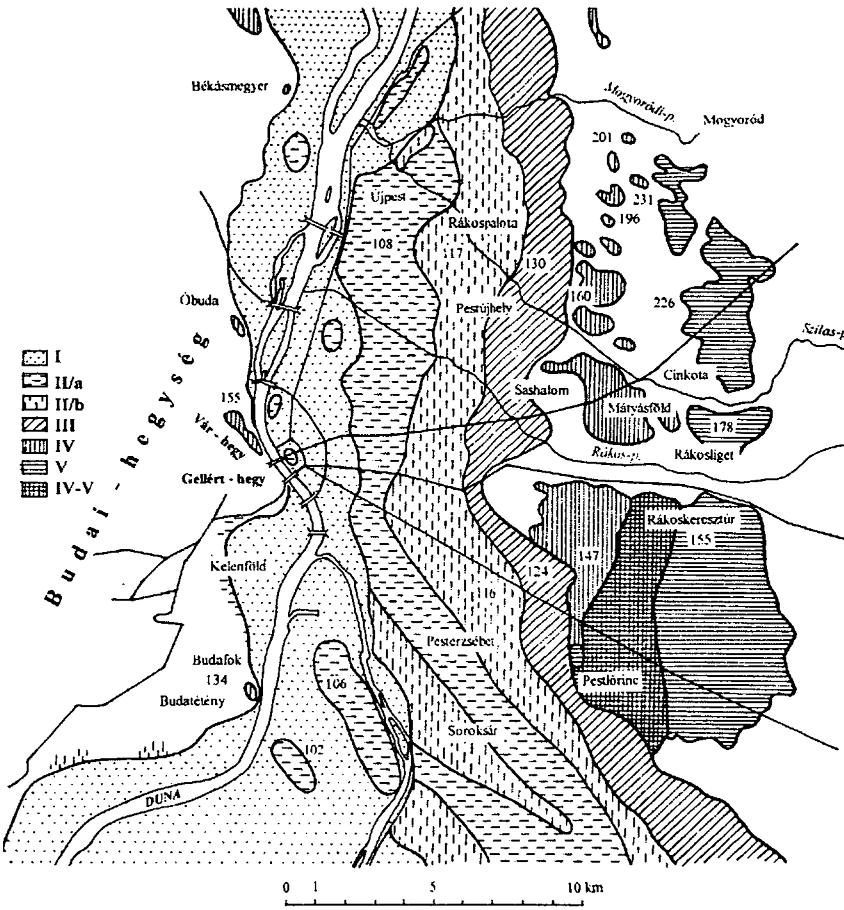
Introduction - aims

The investigation of lose clastic sediments in the vicinity of Budapest has ever been an open issue in the Hungarian geologic–geomorphologic literature. For one and a half centuries a series of researchers have examined the material composition, the formational conditions and the age of the sediment of diverse facies, that was deposited partly under our capital city, and partly in its close vicinity during the latest periods of geologic history.

In spite of the numerous publications on the gravel-bed that is in an uplifted position in the North, and that is claimed to be old, the age and way of its formation is still an unsolved question. These gravels were given several names by the different authors, nevertheless, in the classical geologic literature they are named – after *Halaváts, Gy.* (*1898*) – as "Mastodon gravels" or "Levantian gravels". In recent geologic literature they are mentioned as *Upper Pliocene gravel or Pliocene gravel.* From geomorphologic publications it is known – after *Pécsi, M.* (*1959*) – as Terrace V. Here, in the following it will be called as No.5 gravel-body.

The gravel-body under discussion is the greatest of its kind on the Pesti Plain. It appears on the surface uncovered on the left bank of the Danube in the region of Mogyoród and Kerepes, 250 m above sea level. While widening toward the South its altitude around Csömör, Kistarcsa, Nagytarcsa, and Cinkota decreases to 225 m. Through Rákoskeresztúr, Rákoscsaba, Ferihegy, and Ecser toward Vecsés its surface slopes further, until South of Vecsés, around 130 m, it is already covered by younger sediments (*Pécsi, M. 1959*). Its relative altitude – compared to the 0 point of the Danube at the Lánchíd Bridge: 96,65 m – gradually lessens along the transversal brooks from 150 m to 35 m on a 25 km distance. Its mean slope from the North to the South is 5,7 ‰. In an East-West direction it is practically horizontal. In the region of Mogyoród, Kerepestarcsa and Cinkota it represents two geomorphologic levels, toward the South it gets to the level of neighbouring older and younger formations, and its geomorphologic isolation disappears (*Map 1*).

During the examination of this gravel-body, that is in the highest position from all, in all cases one of the most serious questions of the territory has arisen at once, namely: when did the Ancient Danube – a key factor in the geomorphologic evolution – appear on the territory, and what was its role in landscape evolution? The genetics and the extension of the sediments, that were deposited here in different ways at different times, served as a base for several theories, and are still debated.



Map 1 Alluvial-fan terraces, and delta gravels of the Danube on the Pest Plain (*Pécsi M.* 1996)

I = Holocene flood-plain levels, II/a = Late Pleistocene lower terrace (W), II/b = early Upper Pleistocene higher terrace (R/W), III = Middle Pleistocene terrace (R), IV = older Pleistocene terrace (M), V = gravels of oldest alluvial fans and deltas of the Danube (Pliocen and Upper Miocene), IV –V = delta gravels overlain by the oldest alluvial-fan gravel, 155 = metre above sea level

To overview the abundant knowledge accumulated in connection with the geologic setting, the geomorphologic position, and the evolution of the territory is a difficult task. However, it is far not useless, since the knowledge of the predecessors' results, the gathering and rethinking of their precisely detailed – in many cases irreplaceable – observations are the prerequisites of any further analyses. (*Table 1*)

Contrary to other studies, my aim is not the chronological introduction of the works of different authors, but in order to enable an easier overview, I have separated the features of the "*Mastodon gravel*": mineralogic-petrographic, sedimentologic characteristics, age, and genetics; and I introduce them one by one through the relevant theories and their brief explanations.

Table 1 Summary of the evolution of the theories* of the "Mastodon gravel", based on literature of greater importance (* In the lack of a concrete notion there is a "?" in the table. Concerning age, the difference of former and nowadays divisions must be considered.)

Author	Age	Facies	Origin
Szabó, J. (1858)	Newest Neogene or Lowest Quaternary	?	?
Böckh, J. (1872)	Pliocene	?	?
Szabó, J. (1873)	Upper Pliocene or Quaternary	?	?
Salamon, F. (1878)	Beginning of Quaternary	?	Alp-Carp. and Czech-Moravian
Szabó, J. (1879)	Quaternary	?	?
Inkey, B. (1894)	Upper Pliocene	Alluvial deposit	?
Halaváts, Gy. (1895)	Levantian	gravel cone	Danube
Lóczy, L. Sr. (1896)	Levantian	alluvial deposit	?
Halaváts, Gy. (1898)	Levantian	?	?
Böckh, H. (1899)	Levantian, maybe Pontian	debris cone	Danube
Treitz, P. (1903)	Levantian	debris cone	Danube
Cholnoky, J. in Lőrenthey, I. (1904)	Levantian	?	Redeposited from older - product of torrents
Lőrenthey, I. (1906)	Levantian	?	Galga
Cholnoky, J. (1910)	Levantian	debris cone	?
Strömpl, G. (1915)	Levantian	debris cone	Redeposited from Mio. - product of the torrents of Cserhát
Lóczy, L. Sr. (1914)	end of Pontian	debris cone	From NW Carp.s not the Danube
Schafarzik, F. (1918)	Levantian	delta	Danube
Horusitzky, H. (1924)	Levantian	debris cone terrace	Danube
Schafarzik, F. and Vendl, A. (1929)	Levantian	debris cone	Danube
Pávai Vajna, F. (1937-38)	Levantian	alluvial fan terrace	
Bódi, B. (1938)	Levantian	delta	Danube
Kerekes, J. (1939)	Levantian	?	Danube
Bulla, B. (1941)	Levantian	debris cone terrace	Danube
Mottl, M. (1941)	lower part of Upper Pliocene	terrace formation	
Szentes, F. (1949)	Levantian	gravel sheet (terrace)	Danube
Sümeghy, J.(1953)	Levantian	debris cone terrace	Danube
Schréter, Z. (1958)	Upper Pliocene	alluvial fan	Danube
Pécsi, M. (1959)	beginning of Pleistocene (Günz)	alluvial fan terrace	Danube
Urbancsek, J. (1963)	beginning of Quaternary	debris cone	Danube
Moldvay I. et al. (1966)	Lowest Pleistocene	alluvial fan terrace	Danube
Erdélyi, M. (1967)	beginning of Pleistocene	debris cone	Danube
Kretzoi, M. (1981)	Upper Pliocene	?	Danube
Pécsi, M. (1981)	Upper Miocene and Pliocene	delta and alluvial fan terrace	Danube
Szabóné Drubina, M. (1981)	Upper Pliocene	delta	N-NW accumulation redeposited from Miocene
Kretzoi, M.- Pécsi, M. (1982)	from Pliocene (Ruscinium)	delta and alluvial fan terrace	Danube
Kordos, L.-Jaskó S. (1990)	Lower and Middle Pliocene	delta or alluvial fan	Danube
Pécsi, M. (1991)	Pliocene	delta and alluvial fan terrace	Danube
Pécsi, M. (1995)	Upper Miocene and Pliocene	delta and alluvial fan terrace	Danube

The mineralogic-petrographic and sedimentologic characteristics of the No.5 gravel-body.

Regarding the works on the petrography of the gravel-body, the study of *Bódi, B.* (1938) entitled *The petrographic analysis of Tertiary gravels in the vicinity of Budapest, with special respects to Levantian gravel-formations* is outstanding. By summarising previous observations of *Szabó, J.* (1858, 1879), *Böckh, J.* (1872), *Inkey, B.* (1894), *Halaváts, Gy.* (1898), *Lõrenthey, I.* (1904, 1906, 1912), *Schafarzik, F.* (1910, 1918) and that of his, he found that the major components of the gravels are: quartz and quartzite (90-99%), eruptive granite, quartz porphyry and andesite (1-4%), sedimentary limestone, sandstone, arkose, and shale (1-7%), metamorphic gneiss and schist (1-2%). Based on the directions of *Mauritz, B.*, he originated the greenish-chloritic granite, the microcline granite, and the amphibole granite after *Schafarzik, F.* (in *Lóczy, L. Sr.* (1914)) from the area of Ruttka, Passau and Winden, respectively. Aplites, pegmatites and quartz porphyry were eroded from the Western Alps and the Carpathians, while arkose and sandstones from the lower Mediterranean sequence. Consequently, according to him, gravels were transported partly from the Alps and partly from the Carpathians. He claims that the amorphous iron ore that often gives a rusty colour to the gravels' surface is formed during the infiltration of surface waters containing ferriferous solutions.

Szabó, J. (1879) was the first who drew attention to the andesite varieties that occur in the gravel-bed. Based on his own nomenclature, he named them as trachytes. From long ago, andesites were thought to be of Visegrádian type after *Schafarzik, F.* (1910, 1918); *Bódi, B.* (1938) also described them as andesites from the Dunazug Mountains and the region of Selmecbánya.

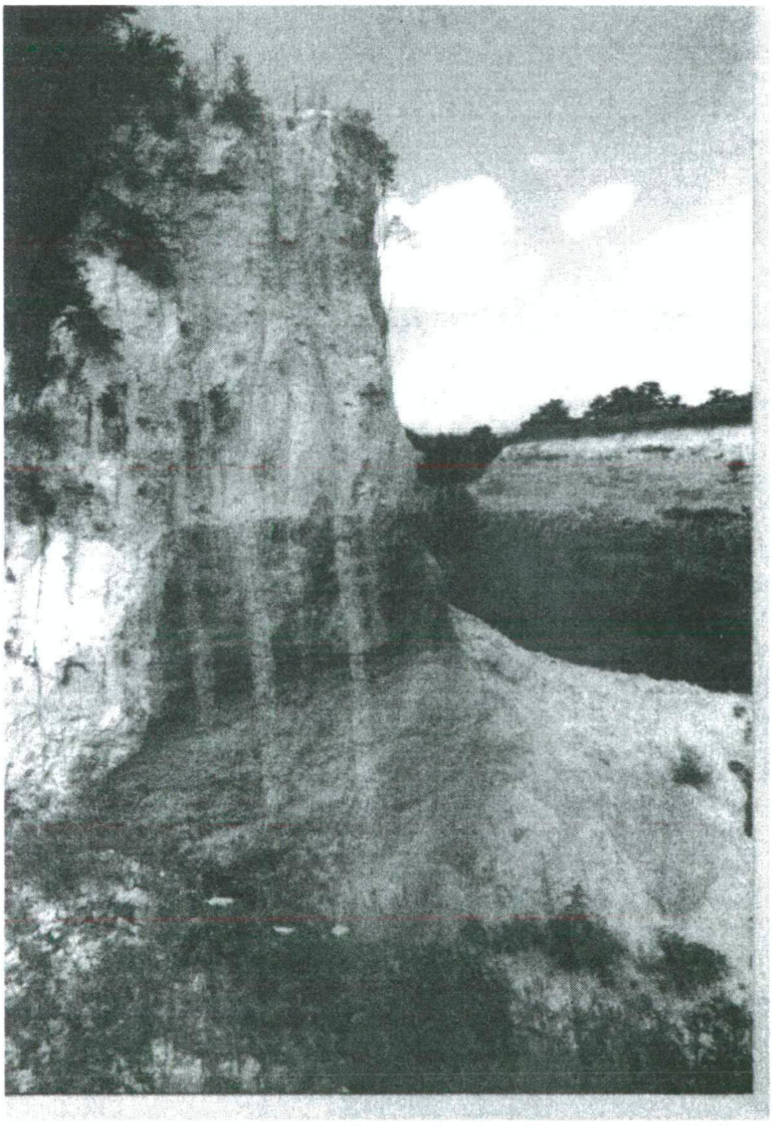
According to the observations of *Pécsi, M.* (1959), from the above mentioned gravel-bed the andesite gravels (he claims that these can be petrographycally separated from younger gravel deposits, that often contain andesite-cobbles, too) are missing, and only andesite or rhyolite *tuff* gravels have larger diameters. The proportion of rhyolite tuff increases toward the South, and contrary to andesite tuff, its altered material is significant in mines North of the Rákos Brook. He also found that gravels of carbonate rocks are very rare in the gravel-body (contrary to younger gravels, where they can be measured in %). He explains this – after *Szádeczky–Kardoss, E.* – with subsequent dissolution.

On the other hand the geologic explanatory notes attached to the 1:10 000 Building Geologic Atlas of Budapest [Budapest Építésföldtani Térképsorozata 1:10 000] (*1981*) – compiled by *Szabóné Dubrina, M.* – reports on andesite-cobbles that join to the base of the gravel deposit, and exceed significantly the local maximum size. Referring to chemical analyses, she emphasises that these mainly amphibole and biotite andesites are not from the region of Visegrád–Nagymaros, but they rather originate from the Miocene vulcanites or redeposited vulcanites of Northeast Pest and the South Cserhát. She assumes that the carbonate rock varieties mainly of Budai Mountains origin are missing because they were not even deposited here.

In his work: *The paleohidrography of the Danube at Budapest* (1918) *Schafarzik, F.* – after *Lóczy, L. Sr.* – gives an account of *"certain silicified nummulitic rocks"* and silicified pieces of wood, that were found among the gravels described as bluish-grey, and were redeposited from the lower Mediterranean sequence. He found these gravels also in the Middle Miocene gravel-bed of Rákosszentmihály (156 m), around Fót (200 m), and on the

Óvári Mountain (327 m) in Nógrád County. The solid form of these silicified pieces of metasomatic limestone of inner Carpathian origin is not known, though, pieces were found at Etyek (*Jaskó, S.* 1939) and in the region of Csömör and Mogyoród, too (*Bartkó, L.* 1939).

The clarifying of the stratigraphic position, origin, and age of the green clay with calcareous concretions *(bentonite)*, that can be found in some places in the gravel's cover, in some places interstratified *(explanatory notice of the 1:10 000 Building Geologic Atlas of Budapest (1981))* may contribute to the solution of problems above. (*Picture 1*).



Picture 1 Bentonite in the cover of the alluvial fan gravel (abandoned gravel mine at Rákoscsaba)

Noszky, J. put this argillic formation, that is at some places 15 m thick, to the *Unio Wetzler* level of the Upper Pannonian (*Noszky J. Sr.*1925). *Pávai Vajna, F.* describes it as the washed up alternation of the calcareous, dried, final product of the fresh watered Pannonian–Pontian inland lake, that diminished under a tropical climate (*Pávai Vajna F.* 1937-38). While, according to *Szentes, F.* (1949), it is the decay of the Middle Rhyolite Tuff that were spread into the sea. The *Geologic explanatory note of the 1:10 000 Building Geologic Atlas of Budapest* (1981) supports also this view. Based on the investigations of *Nemecz, E.*, the above mentioned greenish-grey coloured, plastic, "rich clay" contains Na-montmorillonite, that developed during the fresh water decay of acidic plagioclases, that had originated from redeposited minerals which were capable of hydrolysis among limnic conditions. The most regular forms of such redeposition to a lake are: tuff spreading through the atmosphere, fluvial tuff transportatio, or sedimentation of arkose in the lake (*Nemecz, E.* 1973). We have to notice though that in the same geomorphological position as that of the bentonite, red clay appears (maximum thickness: 14-22 m) in the vicinity of Rákosliget and Ferihegy on the Western edge of the Gödöllői Hills, too *(Geologic explanatory note of the 1:10 000 Building Geologic Atlas of Budapest,*1981*)*. However, this is not a unique case, since bentonite that is deposited on Upper Pannonian sediments and contains red clay in its cover is widely known in the foreground of the North Hungarian and the Transdanubian Mountains (e.g. open cast lignite mines of Gyöngyösvisonta) (*Pécsi, M.* 1991).

The mean and maximal size of gravels, their sorting and roundness may serve as a starting point in determining the hydraulic conditions of the transporter, the distance of transportation, and the place of the gravels' origin, therefore, several researchers have dealt with these parameters. The size of gravels described by *Schafarzik, F.* (1918) are of walnut, rarely of fist, or exceptionally of head size. Mostly, they have flattened spherical, oval shape. They occur together with sharp fluvial sand, that can be found among gravels or in independent layers – long stretching lenses which in some places are *"cross bedded"*.

According to *Bódi, B.* (1938), 1a -1b, 2a (arkose, sandstone, andesite) and 3b, 4a - 4b (granite, diorite, quartz porphyry, gneiss, quartzite) levels of roundness are the dominant, while that of some quartzes are 1a -1b. Both the granular distribution and the roundness of gravels represent diagrams with two peaks.

Pécsi, M. (1959) examined precisely the morphological features of gravels, as well. He emphasises the sorting of gravels, and he claims that the characteristic diameter is 2 - 4 cm. According to him, there are just a few quartz gravels of fist size, and larger sizes can be reached only by andesite and rhyolite tuff gravels, that are often seem to be quite unrounded. He determined roundness with the CPV method, and on the basis of v, he got 6,4 - 7,1. He assumes that the thickness of the gravel-body is 15 - 30 m, and in his opinion its structure is undisturbed, horizontal. He lays emphasis on the great amount of sand, a part of which was redeposited from older sediments, on the basis of the correspondences of heavy-minerals. He successfully separated a younger, unsorted gravel deposit that covered in some places the old gravel-body. This deposit is probably younger with one generation, it is 1 - 2 m thick, it is irregularly stratified, it also contains cobbles, and it represents a lower geomorphologic level (Terrace IV.) westward from the gravel-body.

Several authors found in the upper layers calcareous deposits, vertical gravels, "*wrinkles*", and funnels that are *"filled with sand and some gravels"* (*Halaváts, Gy.* 1898) (*Picture 2*).

Picture 2 Frost wedge in the gravel mine of the Concrete Road Constructing Company at Kerepestarcsa

Inkey, B. (1894) describes these formations as the results of slow slides, induced by the diluvial elevation of the territory. *Schafarzik, F.* (1918) claims that these formations were the results of ice-pack. According to him, the irregular funnel-shaped gravel-sacks were formed during thawing when ice floes sank into the wet ground. He handled these funnels not as a part of the old body, as former authors did, but as a part of a younger gravel-bed that was separated from the gravel-body by him. *Cholnoky, J.* "*was to claim that they are wadi-like lines on the dried surface of the gravel-body, and they were formed by occasional rains*" (in *Lőrenthey* 1906). *Szádeczky-Kardoss, E.* (1936) and *Kerekes, J.* (1939) are the first who correctly explain these formations as fossil tundra formations. Later *Pécsi, M.* (1962 - printed in 1997) deals with these formations detailed, and assigns a dating role to the multi generational cryo-phenomena.

The age of the No.5 gravel-body at different authors

When determining the age of the gravel-body, the occurring fossils are of the greatest importance. Naturally, in connection with these it is problematic to: decide whether these are of autochtonous or allochtonous type; clarify the range of the groups of living beings; harmonise the different stratigraphic classifications.

There are serious debates on where to draw the borders between stratigraphic subdivisions, the existence of which is questioned in many cases. At present, the Neogene - Quaternary border is either marked with the Olduvai event (1,8 Ma) or the Matuyama / Gauss paleomagnetic change (2,4 Ma) (*Pécsi, M.* 1992). This means a significantly longer period than the former, Milankovic - Bacsák concept with its 600 000 year long *Pleistocene*, though, because of older literatures it must be taken into consideration, too. Within the Neogene, the *Pannonian - Pliocene* (in older literatures Levantian or Upper Pliocene) border is put to 5,6 Ma on the basis of Mammalia fossils (*Jaskó, S.-Kordos, L.* 1990).

Schafarzik, F. (1918) believed that older gravels can be divided further. He claimed that the gravels of the Csömör, Cinkota, Kistarcsa region are as old as *Pontian*, and he separated them from the Levantian or even younger sediments that can be found westward in the Rákoskeresztúr, Pusztaszentlőrinc, Pusztagyál, Alsónémedi region. However, he did not support his idea of separation with any kind of petrographical or paleontological evidences.

According to *Lóczy, L. Sr.*(1914), the gravels of Cinkota are originating from periods "*when desert climate dominated on the present territory of Hungary*". In his opinion, as a result of the "Pannonian desertification", an arid climate characterised the Carpathian Basin and the Mediterraneans at the end of the Pannonian period and the beginning of Pleistocene (*Lóczy, L. Sr.*1918).

The name, "*Mastodon gravel*" was created by *Halaváts, Gy.* in 1898, when on the basis of its typical Mammalia fauna he named the gravel-body like this in his work: *The age of the gravels of the Budapest area* [A Budapest-vidéki kavicsok kora]. He found that on the basis of the remainings of *Mastodon avernensis CROIZ. et JOB.* and the *Mastodon borsoni HAYS* molars, he could believe – after *Fuchs T.* – that the gravels between the Pontian sediments and the blown sand are of Pontian age, but similarly to *Szabó, J.* (1858, 1879) he rather declares that there is a younger than Pontian, *consistent* formation that is of *Levantian* age.

While the idea of *Schafarzik, F.* did not meet with a great response, the later point of view of Halaváts, Gy. was accepted and emphasised by every geologist from the last century on: *Böckh, J.* (1872), *Inkey, B.* (1894), *Böckh, H.* (1899) – according to whom, the sedimentation could start at the end of the Pannonian –, *Lőrenthey, I.* (1904, 1906, 1912), *Horusitzky, H.* (1924, 1933, 1935), *Bódi, B.* (1938), *Pávai Vajna, F.* (1937-1938), *Sümeghy, J.* (1952, 1953), *Szentes, F.* (1949, 1958), *Mauritz B.* (1958), *Schréter, Z.* (1958), *Raincsákné Kosáry, Zs.* (1975), *Szabóné Drubina, M.* (1977), *Kretzoi, M.* (1981), *Jaskó, S.-Kordos, L.* (1990), and by geomorphologists: *Strömpl, J.* (1915), *Bulla, B.* (1934, 1941, 1953), *Kerekes, J.* (1939), and *Kéz, A.* (1933).

The formulation of an alternative point of view, that was popular in geomorphologic literature, is noted for *Pécsi, M.* In his monograph on the Danube (1959) based on his own observations /syngenetic covered cryoturbations/ and accepting the standpoint of paleontologists: *Mottl, M.* (1941) and *Kretzoi, M.* (1953) – who found that the *Mastodon borsoni HAYS* is younger than Levantian –, he put the main period of the gravel-body's formation to the Günz, i.e. the *beginning of Pleistocene*. This point of view was accepted by *Rónai, A.* (1959, 1963, 1972, 1985), *Erdélyi, M.* (1967), *Szűts, S.* (1972), *Scharek, P.* (1974), and this can be detected in the explanatory note of the 1:200 000 Geologic Map of Hungary [Magyarország 1:200 000 földtani térképe] (*Moldvay L. et al.* 1966). In his further works he has improved his idea, lately he supposed that there can be much older (Miocene) gravels than Günz–Pregünz, and their genetics is different, as well. He assumes that these are present not just in an uplifted position but in the normal sequence of the Great Plain, on the gravel plane of uniform height that can be found South of Budapest (*Pécsi, M.* 1991).

It must be added that based on the increasing number of Vertebrata findings, the age of the gravels is possibly Pliocene (*Jaskó, S–Kordos, L.* 1990), however, due to inwash processes, the simultaneity of fossils and gravel deposits is uncertain. The role of the abundant findings – found at Pestlőrinc and Ócsa, in boreholes at Szabadhídvég, Tata: Grébics Mt., Martfű, and Győrújfalu – of *Mollussca* species (e.g. *Potomida sturi*) in dating must be considered and examined, as well (*Jánossy, D.–Krolopp, E.* 1994). The correct classification is made difficult by the fact that the fossil can be transported far even by coarse sediments (16 - 18 km), and its seemingly autochtonous position, due to small injuries, can be misleading (*Boda, J.* 1982).

On the basis of its reversed paleomagnetic position, the age of the formerly introduced green clay with calcareous concretions (*bentonite*) is 3,5 - 5 Ma *(Geomorphologic explanatory note of the 1:10 000 Building Geologic Atlas of Budapest,* 1981*)*. The age of the red clay occurring in some places together with the bentonite is debated: *Pécsi, M.* (*Kretzoi M. – Pécsi M.* 1982) puts the optimum of red clay formation to the Ruscinium, while *Jámbor, Á.* (1997) puts it to the beginning of Lower and Middle Pleistocene.

The genetics of the No.5 gravel-body at different authors

Different ideas have been formulated during the researches not just in connection with the gravel's age but the circumstances of their formation, as well. According to some experts, there was a *delta of a river* of great water output, while others say the formation is an *alluvial fan terrace*. None of the concepts can disregard the Danube as a transporter. According to *Böckh, J.* (1872), under the general diluvial cover the gravel fills a Pontian hollow of North-South axis, and wedges out to the East and to the West. His standpoint fits that general picture that was set most completely by *Cholnoky, J.* (1910) and which claimed that the Danube flowed almost all along the Pleistocene in its present wide valley. As a result of a Levantian fault, in the Late Pleistocene it might already follow its present course, at the western edge of the Hungarian Great Plain. On the contrary, according the concept that was first published by *Salamon, F.* (1878) on the basis of *Szabó, J.*, then was worked out detailed by *Halaváts, Gy.* (1895), *Bulla, B.* (1953, 1964), *Sümeghy, J.* (1952, 1953), the Danube flowed till the early Pleistocene (according to *Sümeghy, J.*, till the Holocene) in a transversal direction toward Kecskemét, then Szeged until its direction was changed to North-South by the Kalocsa depression system. On the basis of this concept, the direction of sediment transportation was north-westerly from the Levantian period (according to later investigations – *Pécsi, M.* 1959 – from the end of Levantian, beginning of Pleistocene)

The most important author of the early researches, *Szabó, J.* (1858, 1879) did not deal with the question of genetics. However, we can get know indirectly his standpoint on the basis of the fact, that the originally historian *Salamon, F.* (1878) several times refers to him as a source. Since, he writes about a river discharging into a lake, we can identify his point of view with the recent delta concept. The uncertainty of the geomorphologic nomenclature is proved by the fact that *Halaváts, Gy.* (1895) mentions a *"lake bottom alluvial fan of a river flowing into a lake"*.

At the turn of the century, while examining the numerous exposures of the gravel mines that satisfied the raw material demand of the expanding capital, *Schafarzik, F.* (1918), who was one of the greatest experts of the gravels of Pest, found that the main transporting and depositing factor was a Danube delta. Nevertheless, *Schafarzik, F.*, one of the most influential geologists at the beginning of the century, mentioned separately the oldest gravels of Csömör, Kistarcsa, and Cinkota which were in the highest position, and similarly to *Lóczy, L. Sr.*(1918) and *Strömpl, G.* (1915) he described them as the products of torrents of the Northern Carpathians.

On the basis of sedimentologic evidences, *Bódi, B.* (1938) explains the gravel formations as the gravely - sandy delta of the Danube. This idea was reinforced mainly by geologist circles. One of the greatest supporters of its influence was the 1:10 000 Building Geologic Atlas of Budapest (1981), that was compiled in the 1970s by several authors, and gives the most detailed summary of Budapest's close to surface geological conditions. In the explanatory notes of the atlas the authors take a stand on the delta origin of the gravel-body, but they emphasise that it is not the product of the Danube. According to them, the extended delta of Levantian age is a redeposited material of older, Miocene coarse clastic sediments and vulcanites. The question is: if not the Danube, then which river did accumulate these sediments here with a NE transport? Their standpoint is partly the approval and the general extension of the formerly mentioned, unreasoned theory of *Schafarzik, F.* (1918), to the whole territory, and partly it is related to the views of *Cholnoky, J.* (in *Lőrenthey* 1904), who claimed that the gravels cannot be of fluvial origin because they are well rounded, and they are rather the products of ephemeral streams. Nevertheless, it is doubtful how could torrents accumulate such a great amount of gravels in some places of 20 m thickness.

According to *Lóczy, L. Sr.*(1896), the horizontal stratigraphy of the gravels at Pestszentlőrinc surely refers to fluvial origin, because "*even if the river is torrent and transports cobbles, when it reaches a standing water it drops its deposit immediately and forms beds with a 25 - 30° dip rather then horizontal ones*". *Böckh, H.* (1899) might introduce the alluvial fan (at that time named as debris cone) expression for the discussed sediments of the Pest Plain after this important observation of *Lóczy, L. Sr.*.The difference in their view is that the former author believes that the alluvial fan is a product of Carpathian rivers, while the later one says it is of Danube origin (*Lóczy, L. Sr.*1914).

In the geographical literature the alluvial fan terrace theory has been accepted generally. Beside *Kéz, A.* (1933), *Bulla, B.* (1934, 1941, 1953, 1964), *Láng, S.* (1967), some geologists approved it, too – *Horusitzky, H.* (1924, 1933, 1935), *Pávai Vajna, F.* (1937-38), *Szentes, F.* (1949, 1958), *Sümeghy, J.* (1952, 1953) – and put its formation to the Levantian. Because of formerly mentioned reasons, *Pécsi, M.* continued to claim the formation younger, and by emphasising the undisturbed, horizontal stratigraphy of the gravels, he stated that the alluvial fan terrace character of the gravel-body is proved again. *Schréter, Z.* (1958), *Rónai, A.* (1959, 1963, 1972, 1985), *Urbancsek, J.* (1963), *Erdélyi, M.* (1967), *Szûts, S.* (1972), *Scharek, P.* (1974) and *Moldvay I. et al.* (1966) reinforced this idea in their later publications.

In the exposures of the latest gravel mines of the Budapest region (Kistarcsa, Mogyoród) specially cross-bedded, sandy - gravely sediments can be observed in the subjacent formations of the alluvial fan-like gravel-beds. (Picture 3.) According to *Pécsi, M.*, these are old delta formations that are covered in some places by age marker clay with calcareous concretions (bentonite).

Conclusion

In the following I would like to summarise the most important still unsolved questions:

1. The genetics of the sandy - gravely sediments (*Picture 3*) in the subjacent formations of the alluvial fan gravels is uncertain. Recently, *Pécsi, M.* thinks it is possible that the gravel deposits, that are in a higher position and represent a delta structure, at edge of the Gerecse Mts. (Lábatlan - Öreg Mt., Dunaszentmiklós - Új Mt. - Öreg Mt., Köpite Mt. (*Scheuer, Gy.–Schweitzer, F.* 1988)), the gravels located at higher parts of the Pest Plain at Fót, Mogyoród, Kistarcsa, Rákosliget, Pestlőrinc, etc. (*Picture 3.*), and a part of the gravels in the vicinity of Ócsa are of common age and genetics. He assumes that between 5,0 - 2,4 Ma the Danube deposited sandy - gravely delta formations first on the Kisalföld – on which then it built an alluvial fan together with its Carpathian tributaries. Then after leaving the Visegrádi Gorge in the Budapest region, it built up a delta which was later demolished or in some places partly covered by the alluvial fan formation. The mapping, the determination of the stratigraphical position, and age of these formations require detailed further examinations not just at the present places of their occurrence but in the sediments of the Great Plain, where due to the younger covering formations, their extension is unknown.

2. The examination of the age and formational conditions of the green clay with calcareous concretions (bentonite), that can be found in the cover of the "*Mastodon gravel*", has not got appropriate emphasis in previous researches, though, by all means it is a key point in getting acquainted with the landscape development of the territory.

3. It is a matter of debate how and where do continue older sediments in the sequence of the Great Plain, i.e., how can be the data of boreholes crossing the gravel deposits South of Budapest related to the material of foothill exposures. It is imaginable that the gravel formations have more compound genetics and were formed at different times not just at the Pesti Plain's uplifted, higher strata but in their continuations, too, in the sequence of the Great Plain. At the same morphological level as that of young Pleistocene deposits or under them, there can be much older gravel-beds, as it was brought up time to time by authors from early times till nowadays: *Halaváts, Gy.* (1898), *Schafarzik, F.* (1918), *Pávai Vajna, F.* (1937-38), *Szentes, F.* (1949, 1958), *Sümeghy, J.* (1952, 1953), *Rónai, A.* (1959), *Moldvay L. et al.* (1966), *Jánossy, D.–Vörös, I.* (1979), *Jaskó, S.–Kordos, L.* (1990), *Vörös, I.* (1991), *Pécsi, M.* (1995).

As we have seen, the extremely far reaching issue still brings up some unsolved problems. To answer these questions it is essential to know precisely the theories dealing with the geologic–geomorphologic setting of the territory. This summarising work, without intending to be complete, tried to give help to this.

Picture 3 Cross-bedded gravel deposit in the gravel mine of the Concrete Road Constructing Company at Kerepestarcsa

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CLASSIFICATION OF LANDFORMS CREATED BY QUARRY OPERATION

Karancsi, Zoltán

Introduction

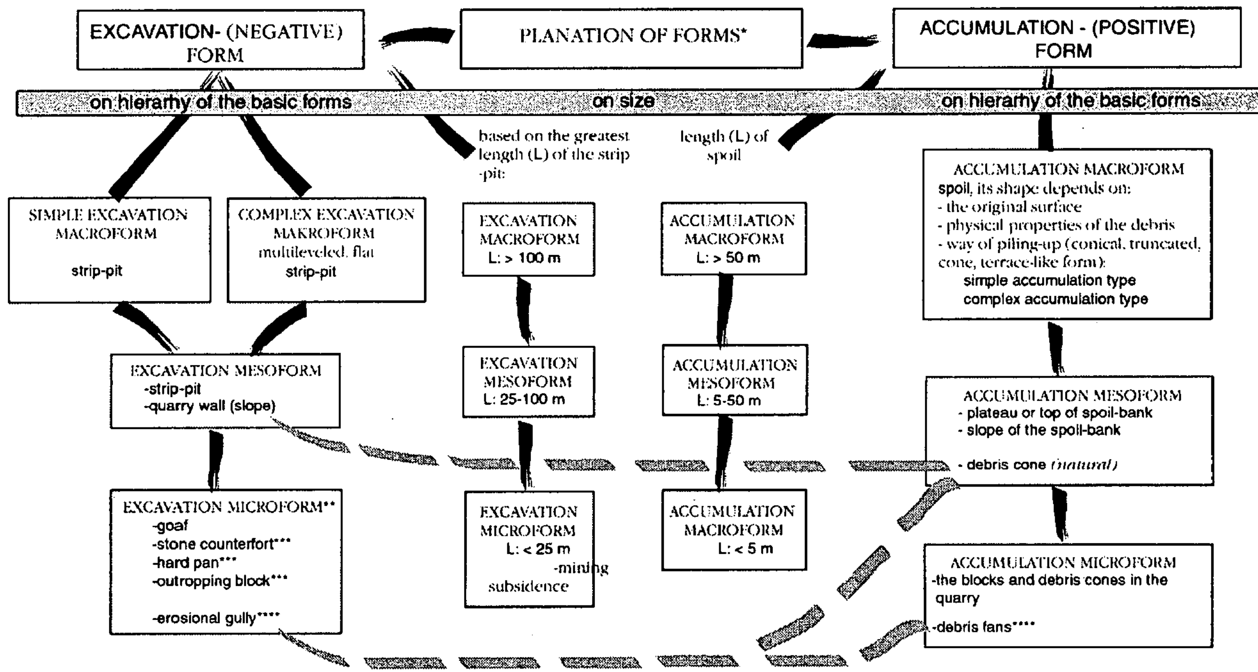
In the Hungarian geomorphological literature the study of anthropogenic influence on landscape was not of great importance until the middle of the 1950s. At that time this attitude changed and in a university textbook "few pages" were assigned to the problems of anthropogenic geomorphology (*Bulla B. 1954*). Since that time several scientists have dealt with the topic – Erdősi, F. (*1966, 1969, 1978, 1987*), Juhász, Á (*1974, 1975, 1976*), Pataki, J. (*1961*), Pécsi, M. (*1971*), Szabó, J. (*1993*), Kerényi, A. (*1995*) and Karancsi, Z.-Mucsi, L. (*1997*).

The quarry operations are the most intensive human interventions that considerably transform the natural environment. The establishment of quarries changes not only the natural vegetation, soils and fauna, but it also demolishes geological structures. Therefore, the circulation system of the groundwater changes as well, and the creation new strip pits and pi-heaps changes the morphology of the landscape too.

Typifying of montanogen forms

The first classification of positive and negative forms created by quarry operation (montanogenous landscape alteration) was created by Erdősi, F. (*1966, 1987*), then by Dávid, L. (*1998, 1999*). We have classified the montanogenous forms following the above two classifications and by complementing it on the basis of our experiments in our research area (the basalt quarries of the Medves Plateau) (*Karancsi, Z.-Dávid, L., 1999, Karancsi, Z. 2000).*

The results of the human intervention can be classified into two groups based on their characteristics compared to the original surface. Those forms which are formed by excavation belong to the first group (*excavational* or negative forms), and those which are created by accumulation are grouped to the second one (*accumulational* or positive forms). The strip pits and the mining subsidences are the excavational forms, while most of the positive forms are the results of piling-up of spoil. The material of the spoil is suitable for levelling the surface altered by quarrying and for filling up smaller abandoned strip-pits (aggradation). The levelling of positive and negative forms is called *planation* (*Szabó J. 1993*).



* the filling-up of negative forms (hollows) AGGRADATION
** based on their origin
*** they are considered as positive form comparing then the excavation macroform (i. e. wall)
**** they are formed by natural processes, as secondary forms

(edited by Z. Karancsi based on J. Szabó and L. Dávid 1999)

Figure 1 Typifying of montanogen forms

The strip mines can be classified on the basis of their area (length of mine) and the complexity of their forms: whether they are of strait or semicircular shape (simple excavational form), or they are multileveled flat mines, described by complex landform types (complex excavational type).

The **excavational forms** can be grouped further based on the *hierarchy or the size of their basic forms* (*Fig. 2*). In the first type of classification the quarries are regarded as excavational macroforms only if they influence the type and aesthetical appearance of the neighbouring landscape with their considerable size. The excavational mesoforms are those goafs < strips < troughs and walls which are within the strip-pits.[1] The stooks between stopes also belong to mesoforms. At the same time, the debris cones along the walls do not belong to the excavational mesoforms, because they were formed by accumulation, i.e., they are positive forms.

The outcropping blocks, stone counterforts, hard pans on the walls and other marks of certain processes (debris flow, land slide) can be considered as excavational microforms.[2] Although, if we compare their position to an excavational mesoform (i.e. wall) these can be even positive forms.

The excavational forms can be preciesely typified according to their *size* as it follows: Strip-pits (walls) with a maximum length more than 100 m are grouped to the excavational macroforms. The greatest length of the excavational mesoforms is between 25 and 100 m, while the microforms are shorter than 25 m.

Based on the *hierarchy of basic forms* the most common accumulation form is the spoil created by piling-up economicly worthless material. At the beginning of the quarry operation all materials covering the rocksurface (e.g. soil) are removed and piled-up as blind spoil. In the case of basalt quarrying all the debris produced during the stonework of ashlars will also increase the amount of spoil. The shape of the accumulation forms depends on the original surface, the way of piling-up and the physical properties of the debris. The development of the surface of these forms is influenced by several active physical and morphological agents, e.g. physical weathering caused by exogene and gravitational forces, chemical weathering, erosion by running water, deflation.

[1] A single strip-pit, a trough in a huge quarry, or even a wall can be excavational macroform.

[2] Those small pits grouped to this type, which are not wider nor deeper than 5,0-m.

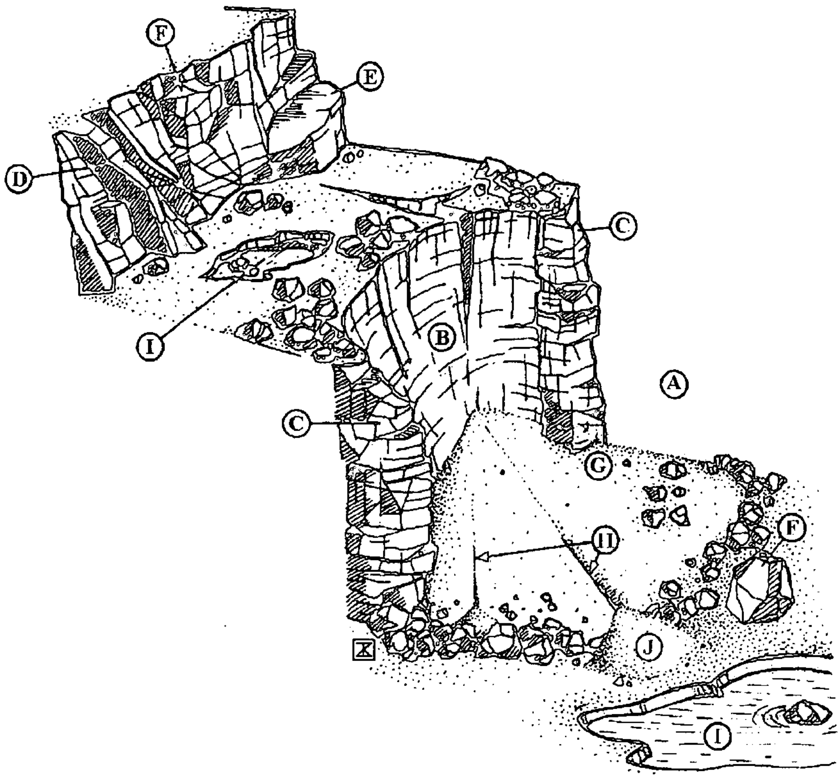


Figure 2 Forms of quarry
A: stip-pit, B: quarry wall, C: pillar, D: stone counterfort, E: hard pan,
F: outropping block, G: debris cone, H: erosion gullies, I: intermittent lakes,
J: secondary debris cone

The shape of spoil-banks depends on the original topography, on the physical and chemical properties of the debris and the way of accumulation (conical, truncated cone or terrace-like forms).

The basic forms of the spoil banks (*Fig. 3*) are plateaus –terrace like top of spoils – and slopes. Concerning the spoil piling techniques, the most characteristic parameter of the spoil will be its length, therefore, we have also typified the spoil-heaps based on their lenght. Spoil banks shorter than 5 m are microforms, while 5-50 m long ones are mesoforms, and those longer than 50 m are classified as macroforms.

On their surface - due to natural denudation – secondary forms will appear, such as debris cones at the ends of the erosional gullies. At the same time, the gully is a typical secondary negative form. Based on their most characteristic feature (height) the slopes of debris can be grouped by as micro-, meso- and macroforms together with their all secondary forms.

Conclusion

On our research area (Medves Region) all the quarries were closed in the middle of the 1980s, therefore, in the last twenty years mostly natural processes reshaped the quarries (illegal quarrying, removal of spoil, heaping waste material and building rubbish also changed their shape). The reclamation plans of the basalt quarries of the region were completed or were under construction by the end of 1998.

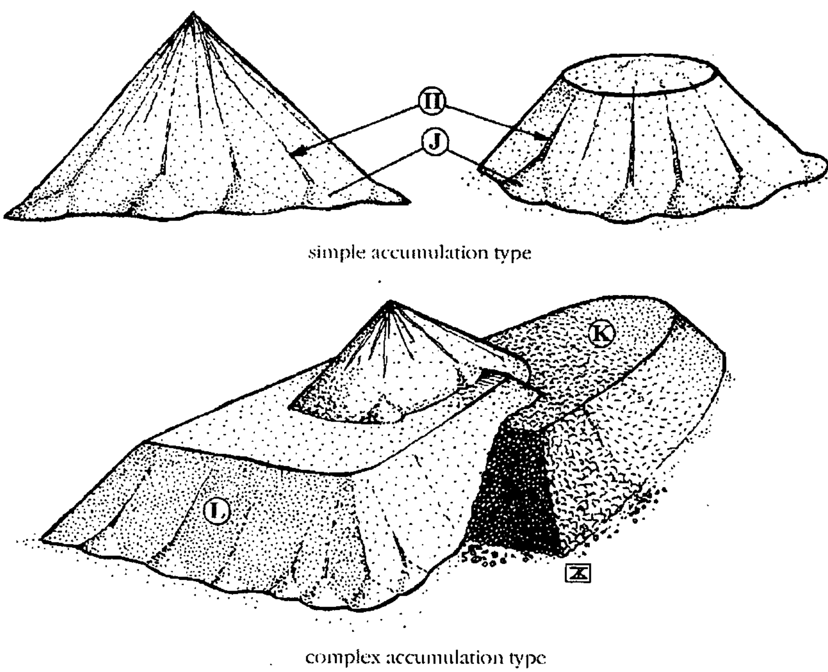


Figure 3 Form of spoil
H: erosion gullies, J: secondary debris cone, K: spoil's plateau, L: spoil's slope

The rehabilitation of the landscape can be carried out by creating terraces in a pleasing order, by planation, by escarping the walls so that the vegetation could occupy the area in a spontaneous way. The most important standpoint of reclamation must be safety. Therefore, after studying the stability of slopes and walls (by sounding) they must be stabilised. In the process of reclamation special attention should be paid for geological exposures revealed by quarry operation e.g. in the Eresztvény Quarry. These are often more spectacular than the natural exposures and they are excellent places for studying different rock beds, morphological forms and several geological processes. These places should not be covered but stops of tourist paths, natural trails should be established, therefore, they could play an important role in education.

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FLOOD CAUSED SEDIMENTATION ON THE FORESHORE OF THE RIVER TISZA

Kiss, Tímea – Fejes, András

Introduction

On the lower reaches of the Tisza two huge floods ran along since the autumn of 1998: one at late fall of 1998 (from November till mid-December) and another at the spring of 1999 (from end of February till the end of May). During both floods very high water level was measured (*Fig. 1*) and both had covered the whole foreshore totally. After the floods passed we have observed sediments of different thickness all over the foreshore. We have measured the thickness of the sediment deposited during the last two floods, and we have tried to estimate the average rate of sedimentation.

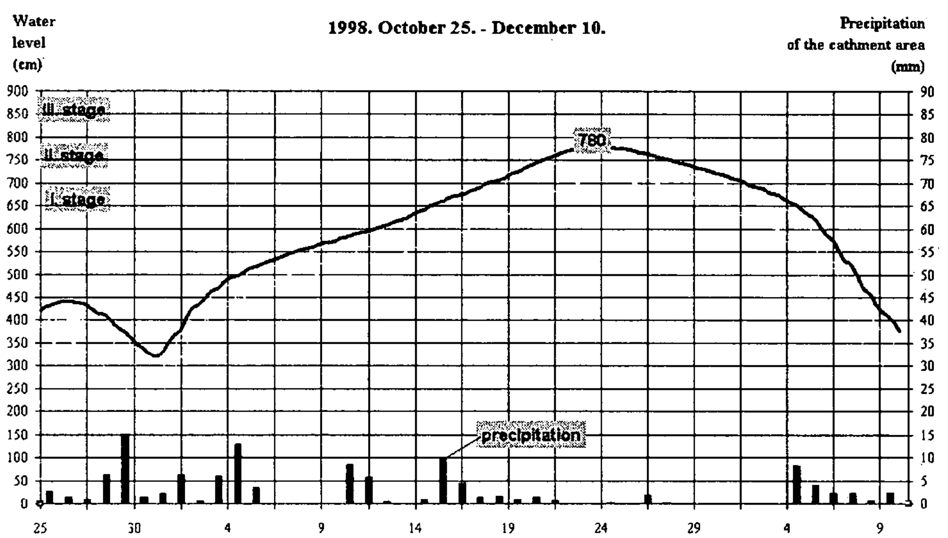

Figure 1A Water levels of two floods in 1998 at Mindszent

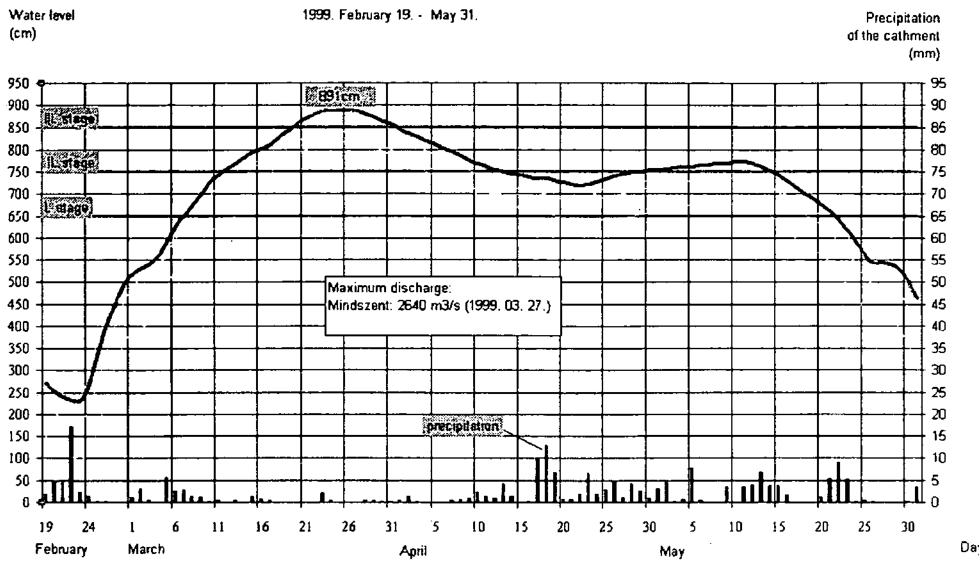

Figure 1B Water levels of two floods in 1999 at Mindszent

Research area

The measurements were carried out on the foreshore of the Tisza, near the town of Mindszent (*Fig. 2*), mostly on the left side of the floodplain, at the inner bend of the river, between two inflexion points. Along the sampling sites the cross-sections show that the floodplain is convex: from the levee towards the river the surface rises, at some places the difference in height can be even 3,0 m.

Along the banks of the Tisza narrow gallery-forest can be found. On those parts of the research area that are close to the town, gardens, vineyards, summer resorts are located. Between the cultivated areas and the levee mostly planted poplar forests, and on the swampy areas willow trees can be found. After the floods passed, considerable amount of sediment was observed on the foreshore. In the newly built channel bars enormous amount of sand was deposited, its thickness reached several meters at some parts. Most of this material slid back to the riverbed during low water.

Methods

The measurements were made along five transects, all together at 106 points. The floods came after the falling of leaves, therefore, the fluvial deposits accumulated on this strata, thus it was easy to measure the thickness of the sediments above the leaf-litter. The only exceptions were those places where the Tisza removed the last leaves, but the good preservation of the yesteryear leaf-litter precluded the possibility of confusing them with those of the former years.

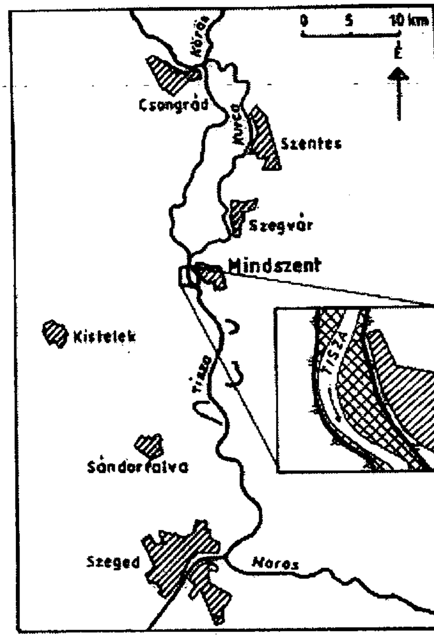

Figure 2 Location of the study area

Therefore, during the investigation we tried to find places where the yesteryear leaf-litter was preserved, where we could handle it as the marker of the bottom of the newly deposited sediment. On those places, where the leaf-litter was missing (i.e. treeless areas) the measurements could be carried out by studying the soil-structure, while in the area of summer resorts the pavements and other solid surfaces marked the bottom of the sediments.

Results

The thickness of the newly deposited sediment varies in a wide range, therefore, for easier evaluation we have used their logarithm, then we have made a map showing the sediment thickness with contour lines (*Fig. 3*). Analysing the figure we can state, that the sedimentation was the greatest on the lower part of the concave bank of the Tisza. In this narrow (10-75 m) riverside area the thickness of the deposits were always over 50 cm. These deposits consist of mostly sand. At some places a rhythm in the fresh sediment – due to two subsequent floods – can be seen: the autumn flood deposited sand, then it was covered by a thick silty-clayey layer; the next sandy layer marks the spring flood, which covered by clay and silt again. This strip is the area of point bar formation.

On most of the area of the bend the new sediment is about 5-10 mm thick, in correspondence with the topography. The best example for the influence of topography on the sedimentation can be studied in the middle part of the bend, where the thickness of the sediment (2-5 mm) is below the average.

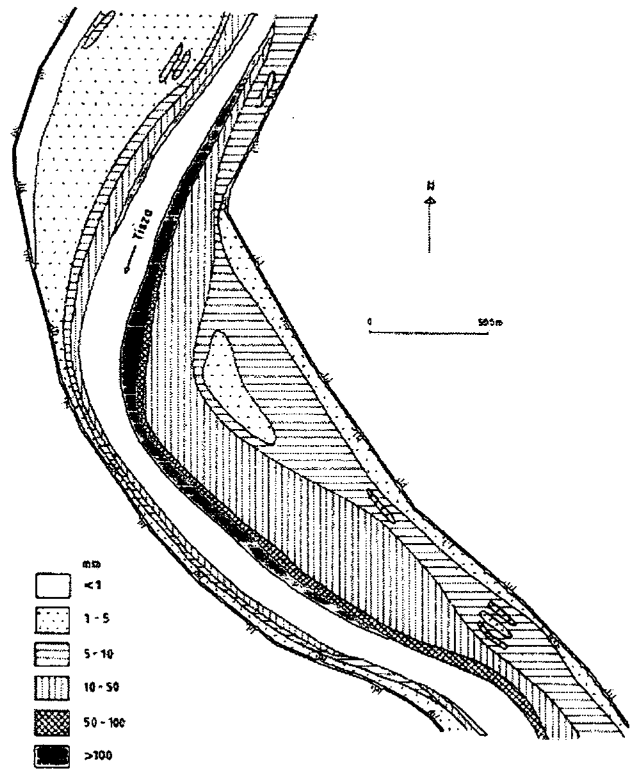

Figure 3 Thickness of sediment deposited by two floods

This can be explained by the fact that this part is higher than its surroundings by 2.0 meters, therefore, the flood covered it for shorter period than the rest of the foreshore.

In front of the levee the thickness of the deposit is greater. We believe it can be explained partly by the natural convexity of the floodplain and partly by anthropogenic activity: the material of the levee was derived from here, therefore it became even deeper than it was, so now it is better sediment trap than the other parts. Because of the fore-mentioned topographical effect, the water stayed here longer, therefore, more clay and silt could deposit here.

On the external bend of the river the amount of sediment is very small, probably because all the measurements are along the inflexional lane of the river.

As a summary we can conclude that the last two floods filled up the foreshore by 10 mm in average. On the riversides, on the bars much more material was deposited, but most of it has got back to the riverbed by mass movements and erosional processes after the flood has passed.

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HUMAN INFLUENCE ON ENVIRONMENTAL CHANGE - RESEARCH ON AN INTERDUNE AREA IN THE SOUTH NYÍRSÉG

Kiss, Tímea

Introduction

The aim of the recent study is to present the characteristics of the landscape development of the South Nyírség, southeast of Debrecen in the late Holocene, to determinate how the human influence affected the processes of natural landscape development, and to specify its way and degree in the different historical periods.

In the neighbourhood of the research area no palynological research have been carried out formerly, and the closest pollen data are from the Ér-mellék (*Félegyházi E. 1997, 1998; Sümegi P. 1992*), from the Kokad swamp (*Csinádi G. 1960)* and from the Bátorliget swamp (*Csinádi G. 1954, Willis K.J. et al 1995*), therefore, they are not suitable for supplying pollen data for our research area. Therefore, we have carried out a pollenanalytical research on the selected site to determine the relative age of the sediments in the interdune hollow and to find out what kind of human influence (if there was any) was characteristic at time of deposition. The discussion of the results do not follow the traditional way, but at first we present the results of the pollen analysis and than those of the sedimentological study.

Research area

During the *Pliocene* and *Pleistocene* epochs in the foreground of the Eastern Carpathians the Tisza and its tributaries built up an extensive alluvial fan, which expanded toward south, south-east. At the beginning of the *Upper Pleniglacial* period (22,000-22,000 B.P.) the Tisza abandoned the alluvial fan and turned to northwest towards the Bodrogköz (*Borsy Z. 1990*), therefore, huge inundation-free areas evolved in the region. At the end of the Pleistocene under the cold and arid climatic conditions the fluvial deposits on the surface were covered by scanty vegetation, which could not provide protection against strong winds, thus, in the unprotected areas blown sand movement took place and the evolution of various sand formations could begin. The most intensive aeolian activity occurred at the first cold maximum of the Upper Pleniglacial period, 27,000-22,000 ys ago (*Borsy Z. 1985*). On the southern part the sand movement took longer, until the Bölling Interstadial, therefore, no loess blanket could form on the surface. In the Bölling Interstadial the climate turned milder and more humid, so the dunes were gradually overgrown by steppe vegetation, thus, the blown sand movement decreased considerably. During the Dryas periods course of sand movements took place, but in much smaller areas than in the Upper Pleniglacial, thus, the forms of the present-day surface were developed in the Younger Dryas (11,300-12,900 B.P.) period (*Borsy Z. 1994*).

At the beginning of the *Holocene* the sand surfaces on the alluvial fan became more and more overgrown by vegetation, so that sand movement practically ceased. Intensive sand movement has occurred mostly since the 18^{th} century as a result of deforestation or overgrazing (*Borsy Z. 1960*). This human influence resulted in the dissection of dunes, though, unambiguous evidence have not been found yet; and even Borsy Z. (*1982*) refers to this as "a sand movement with scarcely distinguishable morphological effect".

The selected site must fulfill some basic criteria: first of all it has to be enclosed by dunes, therefore, the eroded material would entirely accumulate in a basin. The surrounding sand dunes must be tall enough to show intensive erosion due to a possible human impact. Finally, the interdune area must be swampy or at least the groundwater level must be high, since it is the basic criterium for palynological sampling, because pollens are preserved only under anaerobic conditions.

The most adequate site was found SE of Debrecen, west of Újléta in the territory of Bánk Forest (*Fig.1*). This interdune area is bordered by edge dune on the N, W and S sides, while on E a smaller dune can be found. The greatest difference in altitude is 8,0 m between the hollow and the NW sand dune, the other dunes are higher than the interdune area only by 3-4 m. The deepest parts are occupied by swampy vegetation, the higher but still wet parts are characterised by reeds, on the margins willow bushes can be found, while the dunes are covered with pine and locust plantations. The hollow was swampy until 1964, when it was drained. Nowadays only the vegetation refers to the former hidrography.

Methods

Starting from the NW dune 10 drillings were made along a NW-SE section, besides, a trench was made, as well. Samples were taken with a Földvári type hand-drill from every 5 cm. The total depth of drillings reached 180-300 cm. Due to the high level of ground water, the trench could be deepened only on the slope of the dune. Here, samples were taken from the stratigraphic boundaries.

In all, 285 samples were collected from the studied area in order to perform sedimentological examinations. The granular composition of samples was determined with Köhn-pipette, and dry sieving. The pH values were measured from H_2O solution. The calcium-content was determined with a Scheibler type calcimeter. Results were represented for each drillings in diagrams, and in a summed cross-section.

On the cores of a part of the samples (102 pieces) palynological analyses were performed. For the extraction the Zólyomi-Erdtman type, zinc-chloride method was applied. Sporomorphs were determined under a 400-600 X magnification on the level of species, genus, and familia. From the results two types of summed pollen diagrams –absolute value, percentage – were drawn by Tilia and Tilia Graph softwares. Beside determining pollens, fungi spores and algae were counted, too. Later ones were determined on a species and genus level. A sample was considered sterile, if 20 g of the processed material contained less than 100 pollens. The pollen-content of samples became comparable by applying a pollen/cm^2 unit for characterising their pollen distribution.

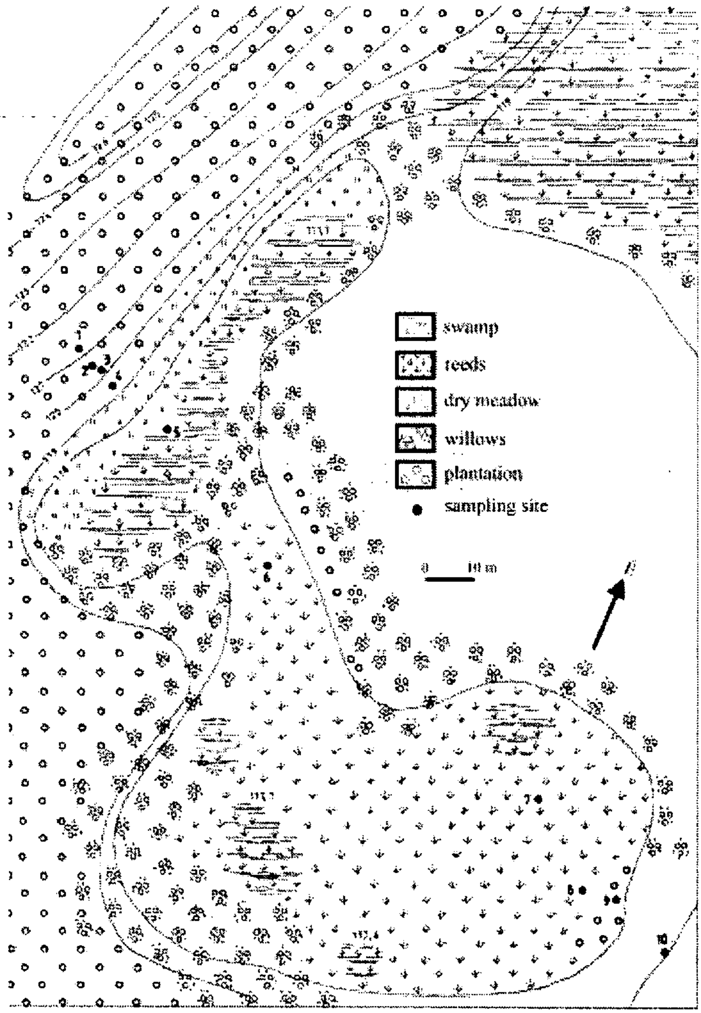


Figure 1 The study area and the drillings

Examinations were complemented with radiocarbon measurements, which were carried out by the Environment Analytic Laboratory of the ATOMKI, Debrecen. Since, during sampling no charcoal remainings were found, analyses were performed on humus. While dating, we applied the generally accepted dating of Andersen-de Vries-Zagwijn (*1960*) that is confirmed with radiocarbon data.

Results

When presenting the results, not the normal way of analysis will be applied but first the palynological then sedimentological the results are going to be set forth. The reason for this is that with the help of pollen analytical data the relative age of sediments, and the possible human impact on the environment are well detectable. However, the characteristics and the pace of landscape development can be deduced from sedimentological results.

For a detailed presentation, the palynological and sedimentological data of the Erd.5-6. drillings were chosen, because these well represent the results of the other drillings of the section. Of course, there are some minor and major differences, but these will be detailed when analysing the stratigraphic profile of the basin.

Pollenanalytical examinations

With the help of pollenanalytical methods we intended to determine the stratigraphical layer's *relative age, the predominant climatic situation during sedimentation, and changes of the surrounding vegetation*. On the basis of the characteristics of climate, we can come to certain conclusions in connection with the course of landscape development, which was also influenced by the changes of the area's vegetation, that provides further information for deciding whether landscape changes were due to natural or artificial factors.

As a reference diagram for pollenanalytical examinations two neighbouring diagrams (Erd.5-6.) were applied (*Fig. 2*). In case of drilling Erd.5. the upper half's, in case of drilling Erd.6. the lower half's pollen content was higher. Therefore, when reconstructing the history of the pollen trap, lower strata were analysed on the basis of Erd.6., while upper strata on the basis of Erd.5. drilling, nevertheless, both were complemented with the additional data gained from the other.

Concerning this interdune basin under discussion, the studied strata's *age* can only be determined uncertainly by pollen analytical methods, since the area from the beginnings might be under human influence (pollens of plants indicating disturbance are dominant, and many of the pollens are shattered or burnt). Therefore, during relative dating a special attention was paid to the presence of phase marking pollens.

The pollen profiles can be divided into two levels, the boundary between them is represented by a sterile stratum (Erd.5. 95-70 cm; Erd.6. 115-55 cm)

In the *lower level* (Erd.6. 290-115 cm) the ratio of pinaceae (Coniferopsida) is high (80-100 %) everywhere. This could refer to a very cold climate, but on the other hand in drilling Erd.6. We have found oak (Quercus) and in drilling Erd.5. holly (Ilex) pollens. The later one is an Atlantic-Mediterranean floral element, it needs an even marine climate and a great humidity (*Gencsy, L. 1997*), and it was a characteristic plant of the Atlantic Phase (*Járainé 1966*). The presence of alder (Alnus) and peat-moss (Sphagnum) also reinforce the assumption that there was an abundant precipitation, moreover, according to the pollens of reeds and sedge, there could be an increased groundwater level in the interdune hollow, as well.

In the *upper level* (Erd.5. 75-0 cm) the proportion of Pinaceae is still high, though for a smaller degree (35-90 %). Regarding deciduous trees, birch (Salix), linden (Tilia), oak (Quercus), popular (Poplus), and also beech (Fagus) are present in a greater proportion. Since, the pollen of beech was found only in one sample, the occurrence of the Subboreal Phase in the pollen spectrum cannot be proved without doubt, however, the proportion of hydrophilous plants, preferring fresh habitats is also high in this stratum, which is not in accordance with the drying at the end of Holocene.

According to radiocarbon data, the age of the upper level's sterile lower part (Erd.5. 80-85 cm) is 3720±65 years BP. Therefore, these results reinforce the assumption that this sterile stratum divides the Subboreal and Atlantic Phases. *Thus, the lower level formed during the Atlantic, while the upper one during the Subatlantic Phases.*

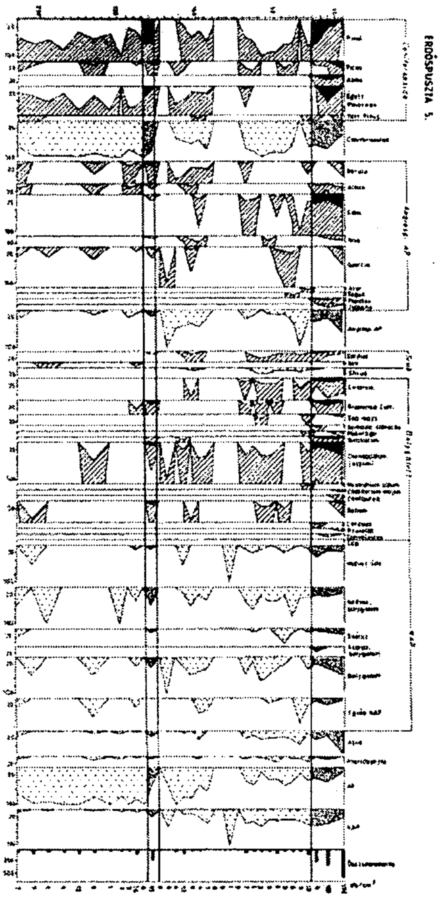


Figure 2a Pollen diagrams of Erd.5. drillings

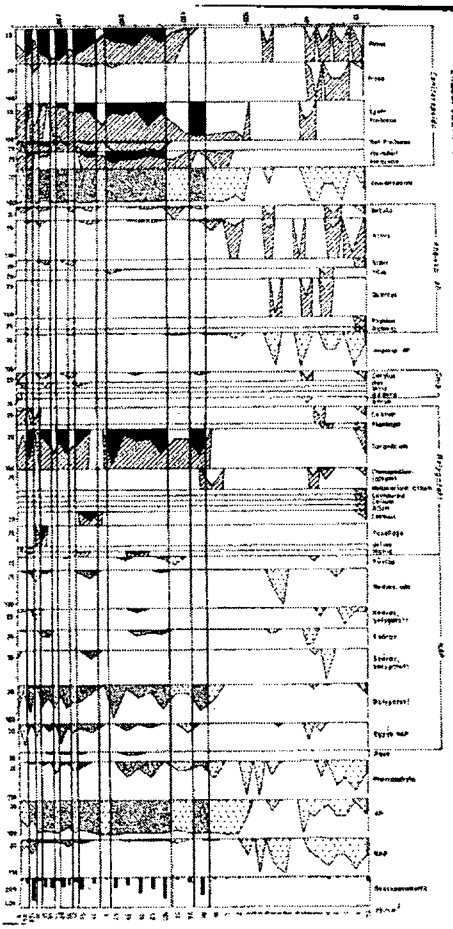


Figure 2b Pollen diagrams of Erd.6. drillings

The most precious and abundant information provided by the pollen spectrum have been those of referring to ***human activity***.

In the *lower level* (Erd.6. 290-115 cm) the number of burnt and corroded pollens is very high. This cannot be explained only with natural causes, since, in this phase we cannot assume such a significant aridity that could reason the occurrence of forest-fires. The pollens of herbs also refer to human disturbance: horse-thistle (Cirsium), lion's tooth (Taraxacum), horse-foot (Tussilago), thistle (Carduus), and nettle (Urtica). All these mean that *the forest was burnt time to time.* The burning-revival rhythm is represented well in drilling Erd.6. Directly after burning the proportion of small- grained sand (0.2-0.1 mm) increased in the sequence of the interdune basin, what refers to inwash or maybe aeolian transportation of the bare dune's material into the basin. The increased erosion occurred repeatedly according to the alternation of pollen-rich and pollen-poor strata, since the redeposited material is usually poor in pollen (*Faegri, K. - Iversen, J. 1989*). Right after the burning the resettlement of vegetation was begun, in the first place by the above mentioned herbs, that indicate disturbance, and pine-trees (Pinus). Pollen-rich strata of this type have a finer granular composition, and corroded pine-tree pollens also occur in a larger number in them. This fact, and the increase of humus-content refer to the beginning of soil formation.

In the *upper level* (Erd.5. 75-0 cm) the pollens imply a change in the type of human activity. Still, pine-trees are dominant on the surrounding territory, but burnt pollens can be detected more rarely and in a lower number. Concerning deciduous trees, the pollens of willow, that has an invaluable wood, are present for all along. The presence of species of hard wood is sporadic in the pollen spectrum. Since, the climate does not reason such disappearance and appearance of trees, we suppose that the forest was cut down regularly. Besides, the pollens of a planted species, walnut (Juglans regia), that occurred in the Carpathian Basin before the Hungarian conquest (*Gencsi, L. 1997*), also appear.

On the basis of NAP pollens, the upper level can be divided further, into two sublevels:

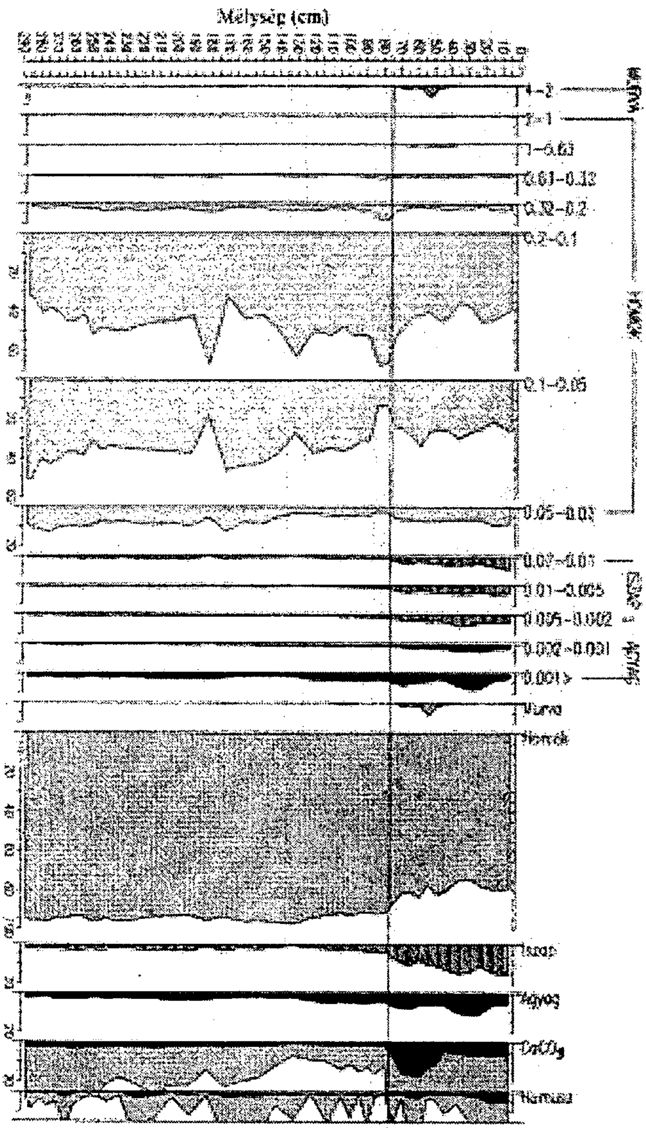
75-25 cm: The increased amount of thistle refers to pasturing on the territory, what is also reinforced by other plants that indicate a strong treading. These are plantain (Plantago), and lion's tooth (Taraxacum).

25-0 cm: In the upper most stratum the pollens of grown plants were found: crops (cultur Graminea), spinach (Spinacia oleacea), maize (Zea mays); and species of weed associations: bindweed (Convolvulus), ragged robin (Melandrium), and goose-foot (Chenopodium). Therefore, beside animal breeding, plant growing also had an important role, and there might be plough-lands and gardens in the vicinity.

Sedimentological examinations

On the basis of pollenanalytical results, we concluded the time and type of the different human activities that affected the area, nevertheless, the question how these activities affected landscape evolution cannot be answered just with palynological analyses. To solve this problem we used the results of sedimentological analyses.

Drilling Erd.6. can be divided into two parts (*Fig. 3*). The boundary is represented by sample 70-75 cm.



Figures 3 Sediment strata of the Erd.6. drilling

In the *lower part of the drilling* (290-75 cm) the proportion of sand fraction is high (≥90 %), though, the amount of small-grained sand (0.2-0.1 mm) exceeds that of fine-grained (0.1-0.05 mm) only to a small degree. The amount of small-grained sand exceeds 70 % only once (125-135 cm), and twice (175-185 cm and 80-85 cm) falls between 60-70 % (both times 67 %). This suggests that once surely but maybe three times the aeolian sand of the dune got into the basin (sediment trap). The humus-content is also very diverse in this zone but remains usually under 1 %, however, in an upward direction with an increasing frequency (in eight occasions) its amount grows significantly (1.2-2.7 %). This could happen only in case these strata were on the surface undisturbed for a longer time, and soil formation could begin on them. In those three cases when the sand of the dune got into the basin (aeolian or fluvial process), the material covered the strata of higher humus-content. The organic matter content of the thickest humus-rich stratum (145-175 cm) is 1.7-2.3 %, which implies a longer period of soil formation.

In the *upper part of the drilling* the proportion of silt and clay fractions increases. Oolitic marsh ore concretions appear in this zone (45-60 cm), too. Their presence can be concluded from the increased ratio of rubble (≥1 mm) fraction. Above this stratum the proportion of calcium grew to an unusual level (16-17 %) compared to that of the calcium-poor sands of the Nyírség. This can be both of organic and inorganic origin, and previous pollen analytic investigations (*Csinády, G. 1954, 1960, Willis, K. J. et al.*) always dated it to the Atlantic Phase. Toward the surface the amount of humus gradually increases, and the upper most 40-50 cm is represented by a dark coloured swampy stratum.

An outline of the stratigraphic sequence of the studied area

In order to compare drillings we set the diagrams of their granular composition. As a result of comparisons we drew the stratigraphic cross-section of the basin, during which we considered the following principles:

Little differences in the quality of strata are important, too.

The naming fraction(s) of the stratum is not necessarily the one that is of the greatest proportion but the one whose amount increased significantly within the stratum.

I paid special attention to the ratio of small-grained sand (0.2-0.1 mm). According to Borsy, Z. (*1960*): "small-grained is the dominant in the blown sand of the Nyírség". He also published the mechanic composition of some exposures, and the proportion of small-grained sand reached 76-86 % in these. Our own experiences also support the fact that on the studied area the proportion of 0.2-0.1 mm sand fraction always exceeds 60 % in the sand of dunes. Therefore, when we found a stratum where the proportion of small-grained sand was higher than 60 %, then we regarded it as the redeposited material of the dune, and if this stratum stretched along the whole basin, then we concluded that it was of aeolian origin. However, if this layer wedged out near the dune, then we handled it as a redeposited_material, since, according to previous measurements, the material of the dune cannot be transported far by the erosion induced by precipitation (*Kiss, T. 1997*).

In the enclosed basin the material of the drillings, similarly to that of the valley, can be divided into three levels (in Erd.6. only the lower two occurred):

the lower most level is rather sandy, the proportion of fine-grained and small-grained sand is high (these two fractions give approximately the 80 % of the sediment);

the middle level is a more silty, more clayey stratum, that wedges out in the base and in the side of the dune. It was the thickest (0.8 m) at drilling Erd.7.;

the upper most level, the material of the dune was exposed on the western edge by drillings Erd.1-4., on the eastern edge by drillings Erd.9-10.

In the *lower most level* the strata stretch along the whole length of the basin (*Fig. 4*), strata that wedge out or in can be found only at the base of the dune. Those three strata that contain sand of aeolian origin and appeared in drilling Erd.6. are present in all the other drillings, too. Thus, these refer to erosion activities caused either by wind or precipitation – that affected the whole territory of the basin, and the neighbouring dunes.

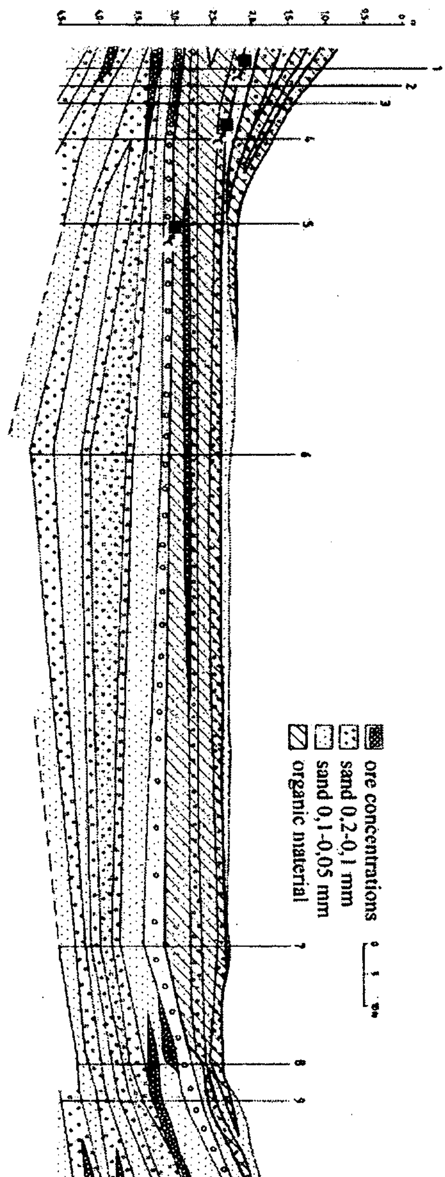


Figure 4 Stratigraphical sequence of the studied interdune area

The *middle level* is the one that appears on the surface of the basin, and that is buried in the western edge, while it wedges out at the base of the eastern dune. A general characteristic of it is that the proportion of grains smaller than 0.05 mm (in average 20-25 %) increases in it. In the bottom of the zone a stratum, consisting of mainly fine-grained sand, can be found, from above which in drillings Erd.5-6. marsh ore concretions turned up. These are covered in the middle of the basin by the calcareous accumulation that was detected in drillings Erd.6-7. The maximum calcium content (19.5 %) was found in drilling Erd.7. at 40-50 cm. The $CaCO_3$ accumulation is generally covered by a stratum with an increased proportion of fine-grained sand. On the surface its amount gets higher again, and parallel with it the humus-content increases, too, and reaches up to 4-5%.

This levell has the characteristics of the sediments of interdune areas: iron concretions and calcareous precipitations refer to a strong influence of water; as a result of the beginning of soil formation the amount of silt and clay is high. Due to redeposition, this zone can also be found at the NW end of the cross-section, under the dune, but similarly to the SE end it wedges out quickly.

The upper most level was separated in the western edge and in the eastern edge on the basis of drillings Erd.1-4. , and Erd.9-10., respectively. The summed proportion of silt and clay at this level does not exceed 4-5 %. Small-grained sand is dominant (>70 %), the humus content is low. This level must be regarded as the material of the surrounding dunes. The fact that the thickness of this stratum continuously decreases, while eventually in drilling Erd.6. it disappears, means that the sand was washed in the basin gradually, and covered its muddy sediments.

Conclusion

Based on the palynological and sedimentological analyses of the drillings of the interdune basin, and with the help of archaeological findings and written documents that originate from the area, it is possible to reconstruct the natural and artificial impacts that affected the sampled territory and its surroundings.

We can reconstruct the evolution of the landscape from the Atlantic Phase (7500-5000 BP.), since this was the lowest stratum that the drillings reached. The warm, wet climate would have been favourable for the development of mixed oak forests. But on the contrary, oaks grew in the area just occasionally, because their habitat was occupied by pine-trees, that could regenerate faster after forest-fires. Natural fires under prevailing climatic conditions did not or just rarely could occur, thus, it is probable that such frequent forest-fires can only be explained by human influence. Consequently, the people of the Neolithic Age had been doing shifting agriculture that required regular forest burning. The cracked and eroded pollens that we found, and the fact that the material of the dunes got into the sediment trap from time to time refer to an intensive soil erosion. Hence, from this stage the lowering of dunes probably started, their slopes became gentler, and in the basin on the redeposited material soil formation began at least eight times – on the basis of sedimentological analyses.

The place of the early stage of the Subboreal Phase is uncertain in the profile, but according to ^{14}C measurements, it might be at the bottom of the sterile stratum (70-100 cm).

Supposedly, Pinus species and different deciduous trees grew on the dunes at this period. Under the cold, wet climate of the phase the level of ground water in the interdune basin increased continuously, and there might be even an open water surface.

The NAP pollens imply that the territory was used for pasturing. The wet, swampy basin was ideal for animal breeding, since even in the hottest summer the wet hollow could provide some grass for the stocks, then in the winter the heat of the rotting material of the swamp might melt the snow, and animals could find feed again.

The relatively rich archaeological findings of the area refer to Copper and Bronze Age settlements. According to Mesterházy, K. (*1984*): "we can count on a quite dense population", and the appearing of the Nyírség culture is also dated to this era. Maybe, due to the increasing importance of agriculture and the decreasing role of animal breeding – especially in the Copper Age, but in the Bronze Age, as well (*Kovács, T. 1977*) – we did not find evidence of significant erosion in the sequence of this phase. This might be explained by the assumption that in case of agricultural landuse the degree of erosion is smaller.

In the **Subatlantic Phase** the composition of the surrounding sparse forests (proportion of tree pollens is low) could be very mixed. The hollow, that remained wet, was framed by reeds and sedge. A more widespread agriculture characterised the territory at this phase. Mainly crops and maize were grown. Deforestation could also be significant – numerous burnt pollens were found –, however, pollens of non-native species (locust, walnut) that refer to tree plantation, appear too.

The human activity became more and more significant, and caused the transformation of the environment: erosion started on the bare dune, and the swamp of the interdune basin was partly covered by its eroded material. On the basis of radiocarbon datings (1060±65 B.P. and 825±65 BP.) this might happen in the 10^{th}-13^{th} centuries. On the basis of contemporary remainings and written documents, at this time Bánk, a settlement near the studied area, was a populated village with a church – it disappeared only in the middle of the 16^{th} century *(Zoltai, L. 1932, Győrffy, Gy. 1966*), consequently, there could be agricultural activity during the ages of the Árpáds. Nevertheless, this does not mean that all of the fields around the village were cultivated: according to contemporary documents, there were huge forests in the vicinity of the settlement in the 14^{th}-15^{th} centuries (*Zoltai, L. 1932, Jakó, Zs. 1940*).

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ARE THE LANDSCAPE TYPES WELL DEFINED FROM STATISTICAL POINT OF VIEW?

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Summary

In landscape ecology (and in geoecology) the different research groups interpret the smallest units of the landscape differently. Several ideas exist between the ecotope and the landscape unit. As far as the landscape is built up of these units and they used widely in comparative analysis, it would be proper to ask how well defined mathematically these units are and the derived systems traced from them. This determines the types of operation allowed to make among them.

In landscape ecology many types of parameters exist. To describe the landscape units and landscapes and to analyse them different data types (ratio, interval, ordinal, nominal) are available. Their usage together, however, is limited because of mathematical reasons. Several examples could be quoted as the misinterpretation of these parameters.

We have made an attempt to create statistically well defined units. We have used the following method: at first the different types of variables were subjected to cluster analysis, and than these were traced back to nominal level. Than we have created a map, based on these parameters and we have compared this map with the landscape ecological one created by traditional survey methods. Cross-tabulating these two maps we have analysed how well defined the units statistically are. The degree of similarity was different from place to place and according to the ecological characteristics of the units. The most well defined are arable lands on slopes 0-12%; the small gardens and meadows on silty soils and pasture lands.

The (regional) units of the landscape

Studies in landscape ecology may have a variety of different aims. The most common are those based on the analysis of homogeneous units or ecotopes intended to disclose the **structure** of the landscape. Such studies seek to analyze the complexity of the landscape as a means of revealing inner connections. Another approach is the **functional** analysis of the landscape. This is more of a practice-orientated approximation, dealing with the optimal utilization of a landscape and the exploration of its resources and their potential (*Leser, H. - Klink, H. J. 1988*). The motto of this kind of study is that "each landscape has its own geoecological problem". Recently, in applied landscape ecology, **process-orientated** analysis has been the focus of attention (*Mosimann, Th.1991*). In this case the landscape is frequently referred to as a system and the researchers study its functioning (i.e. landscape household).

All of these research approaches have a common feature: they require the definition of a spatial unit, though they do this in a variety of ways. Several studies have made an attempt to define this as a **statistical** unit (*e.g. Westerveld, W.G. 1984, Mezősi, G. 1986, Pohlmann, H. 1993, Saldana, A. et al 1997*).

Ecological analysis always raises the issue of regional units, and the meaning and interpretation of these regional units can be varied from study to study. The fundamental unit is the ecotope or landscape unit. The first one is very frequently used in the geo- and bioecology. In the landscape ecology and bioecology, ecotope is defined as the smallest homogenous living space. In geoecology, it is the spatial extent of abiotic geo-systems, though these are often related to biotic factors. In our opinion it would be more expedient to regard the ecotope as the smallest spatial element of the regional ecosystem including both biotic and abiotic factors. Some of the different interpretations of the smallest, but still homogeneous (in ecological sense) fundamental units (e.g. facies, ecotope, landscape unit) are compared in *Table 1*.

Dimension	scale	appr. area	Neef 1963	Haase/ Richter 1965	Iszacsen-ko 1965	Wittlesey 1954	Schmits-hüsen 1949	Zonne-veld 1972	Wieneke 1987
Topical	micro	10 m^2 - 1 km^2	*Ökotope**	*Ökotope**	*Facies*	*Site*	*Fliese*	*ecotoop**	*Ökotope**
Choro-logical	mezo	1 km^2 - 10^3 km^2	*Ökotop-gefüge* *Meso-chore*	*Mikro-chore (Ökotop-gefüge) Meso-chore*	*Urocsis-cse Meszt-noszty Landscape*	*Locality* *District* *(Section)*	*Fliesen-gruppen Naturra-umliche Haupein-heit*	*land facet* *land system*	*Ökotop-gefüge Mikro-chore Meso-chore*
Regional	macro	10^4 km^2 - 10^5 km^2	*Makro-chore* *Mega-chore*	*Makro-chore*	*Okrug* *Province*	*Province* *Realm*	*Naturra-umliche Grossein-heit Natur-raumliche Region*	*land-schaft*	*Makro-chore Mikro-region Meso-region Makro-region*
Global	mega	above 10^6 km^2	*Geo-region*		*Zone*	*Geogra-phische Zone*			

Table 1 Geoecological and landscape ecological classification (after *Leser, H. 1991 and Huggett, J. 1995*) (*The ecotopes are the smallest units, and depending on the type of landscape their area varies from 10 m^2 to many km^2. They form different functional units based on structure and active processes.)

While in the English literature the "landscape unit" is more frequently used with a kind of neutral meaning, in Russian and German writings the separation of the typological elements of the landscape becomes more typical. The Hungarian scientific practice distinguishes sharply between typological (functional) and structural (topological) categories. Both are used to define landscape units, but are used independently (*Pécsi, M. 1972*). The reason for this division is probably that the main goal of many studies was meso-scale investigation in which the researchers did not face conflicts between the two concepts. A similar hierarchical system encompassing both conceptions — the ecotopes and the landscape typological classifications — can be created. The different levels are linked in the same way as far as the elements are concerned, only the point of view is different. The structure of these units is the same or similar, the biotic, chemical and physical properties are comparable, the ecological processes are alike, and their size is typical as well.

Undoubtedly some of these elements exist in reality (i.e. ecotope); others are results of some kind of synthesis or standardization (i.e. typological elements - agrarian landscape in lowland position covered by chernozem). In practice, the following questions arise: How can these elements be separated and in which case are they considered as diverse? To answer these questions, we can use distinctive characteristics of sand features, which are related to scale, dimension, and complexity. There are however difficulties in analyzing these characteristics statistically. Some types do not meet the requirements of commonly used statistical tests. We can find statistical mistakess in several geoecological investigations: for example a typical error is that some parameter categories (i.e. land use categories) are described quantitatively and then analyzed statistically. Unfortunately at many cases these categories do not meet the mathematical requirements of statistical analysis. In the following, therefore, we try to collect and present satisfactory methods for achieving correct statistical analysis.

Parameters in landscape analysis

Two problems arise with respect to the parameters used in statistical analysis of spatial units.The *first problem* is that they can be very different, limiting their ability to be used to study widely. In the geoecology three characteristic parameter types are used. The nominal type of parameter data gives information only about whether an element is a member of a set or not (i.e. soil type, land use, vegetation type). Of course these nominal parameters we used can be numbers as well, but in such case they are suitable just for identification. The values of the second type of parameter give a sequence (an ordinal), or it is possible to determinate the interval into which they fall (interval variable). In case of individual value for each interval in some respect will refer to the sequence of the characterized data. In the geoecology the variable of interval types is often derived back to the ordinal type. Variables of interval type are e.g. slope angle, grain size distribution. Derived values of ordinal type are e.g. slope categories, mechanical soil composition. Pure ordinal type of variables exist as well, like NDVI-value calculated from the satellite data or the fertility classes of soils. The parameters of the third group are the result of such measurements, which have an absolute "0" point and numbers that are rational to each other. Therefore, these kinds of variables are called ratio type of values. These parameters are very often produced by conventional measurements, like the amount of precipitation, the data of soil chemical analysis, elevation etc. The classification of the variables can be modified by considering whether they describe point-like or spatial data: for example the proportion type of slope angle data, measured on points, are interpreted as ordinal type of slope category in the spatial analysis.

Therefore, we worked with very different types of data in our geoecological investigations. But there are considerable reservations to use, the different types of data should not be treated in the same database. For example we can not make statistical analysis using nominal (i.e. vegetation type) and interval variables (i.e. slope exposure) in the same time; or we can not give numerical values for the vegetation types and analyze them together with the interval variables, because of the statistical rules. This is irregular and it gives false results. Unfortunately several false analysis (factor and coherence analysis) occur in the geoecology.

The *second problem* is how to integrate the great amount of data used in geoecological analysis. Often only groups of so-called "key-parameters" are analyzed (usually just a small portion of the originally used parameters) and these are used to make generalizations about the entire database (*Westerveld, W. G. 1984, Mezősi, G. 1986*). The only problem is that the determination of key-parameters requires the statistical analysis of the entire database in advance of the ecological one. Though, if we have to use different parameters because of the spatial and temporal variances, the key parameters will not mean too much help. The question is how to integrate all types of data in the ecological analysis.

There are two solutions to this problem in geoecology. The first is to use integrated categories such as ecotopes or other typological landscape units from the beginning of the analysis. The difficulty here is that, as noted above, the definition of these units varies somewhat from study to study (see Leser, H., 1991, or Naveh, Z. - Liebermann, A. S. 1984) and scientists may group the same units into different classes using different methods and approaches. The real trouble is that the borders and limitations of the integrated units vary considerably depending on their position in the hierarchy of the ecological system being considered. That is, the extent of a single geoecological process or element can be drawn as a homogenous unit at a particular scale with a well-defined size and border (*Mosimann, Th., 1990*). These units however may lose their homogeneity when viewed at a different scale from another level in the ecological hierarchy. The possibility exists, however, to use statistical methods to decide whether and under what conditions to draw borders around homogenous units when viewed from different levels of a hierarchy.

The second solution is to build the analysis stepwise from single parameters, and decide on the method of integrating the parameters as they are combined. Various methods for weighting and categorizing the parameters can be used. The basis of this method is holistic environmental observation. The problem is that one can never be sure about how to interpret the results nor whether appropriate statistical operations have been performed throughout the analysis. However, this method is very much in keeping with the ideas of the German landscape ecological surveying using 1: 25,000 scale maps (*Leser, H. - Klink, H. J. 1988*). Though, they summarize the apparently neutral potentials and functions, like agroecologial potential or the summary of runoff-regulating function (*Fig. 1*). As a matter of fact the question is how to create a new map using the available ordinal or scalar (continuous numerical) maps. In this case the new map consists of nominal variables, which were created by the qualification of the former maps.

Methods of the analysis and its results

Our investigation was carried out on a Hungarian test area in the Bodony Basin of the Mátra Mountains. In this basin a geoecological survey have been carried out (*Mezősi, G. - Rakonczai, J. 1997*). All the important data and maps were available for the analysis, including the map of the landscape units constructed on the basis of traditional methods. There were several ways to create statistically well-defined units. The one employed here was to create unit-groups based on similarity. The statistical method will be compared to the survey method.

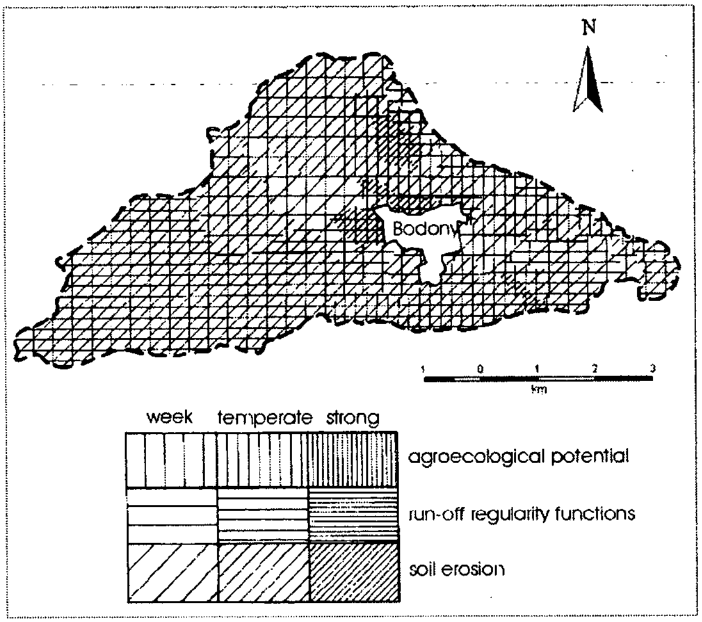

Figure 1 Landscape ecological map created by combining the agroecological potential, soil erosion and run-off regulation function (Bodony Basin, Mátra Mts., N-Hungary)

The basis idea of the method applied was the reduction of all variables to the nominal level (*Fig. 2*). However, this reduction was not done in one single step, because much information would be lost. The following method was used instead. First, cluster analysis was performed on all ratio variables (*Fig. 3*) to reduce them to ordinal level. We have made another cluster analysis on this database and on the other ordinal type of data, creating a cluster map, which is on the nominal level now. It carries the ordinal and ratio type of information, and besides these, we have lots of nominal data (i.e. land use) independent from the above mentioned ones. The difficulty was that on the nominal level the cluster analysis could not be carried out in the traditional way. In order make a cluster analysis some criteria have to be completed, but in our case the data do not have normal distribution.

We searched for such a method for separating the units, which avoids the problem of weighting parameters among each other's. Namely, the parameters used in practice do not have the same importance (Solncev Rule; *Mezősi, G. 1986*).

This kind of weighted is originated from the order of the maps, as we use them, one after the other, for drawing borders. For example, we started our research with the land use or the slope category or the soil-type map — depending on the topography —, and then the borders of the chosen map will be dissected further on, using other new parameters. We will come up against the problem of distinguishing ecotopes, both if we use weighted or integrated units (see 2. chapter) or the parameter method.

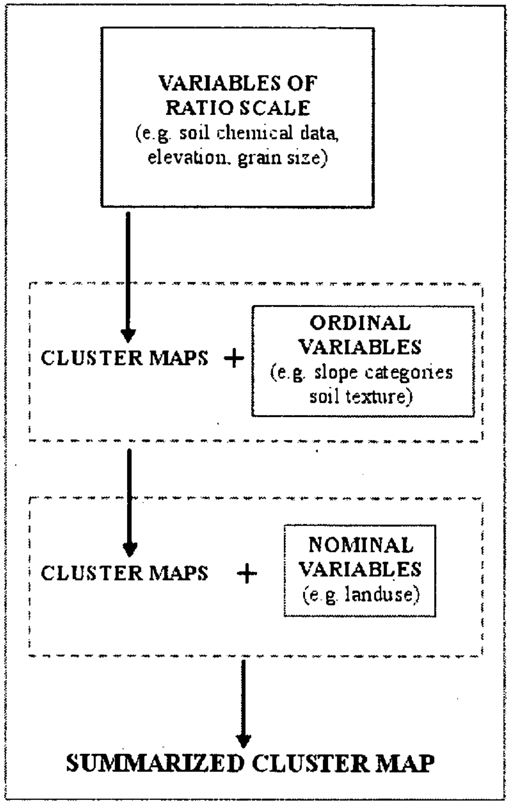

Figure 2 The steps of the analysis

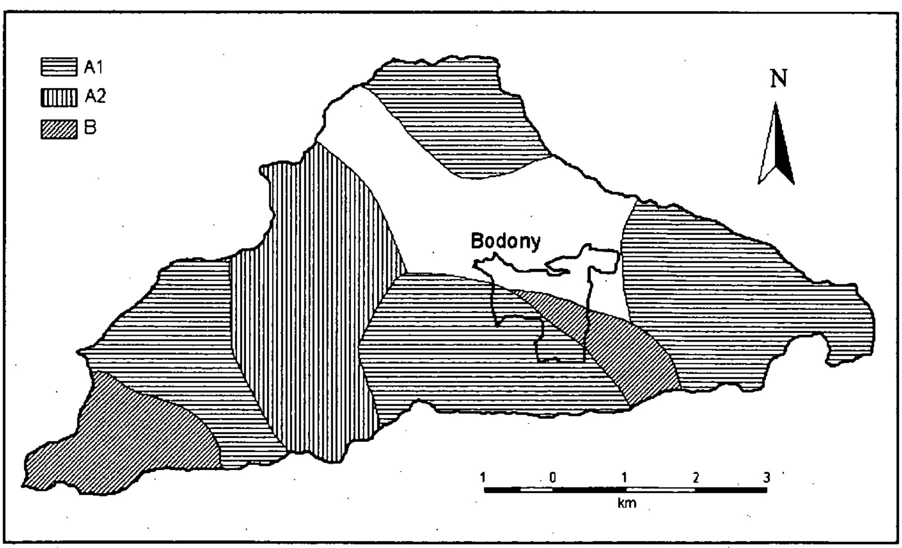

Figure 3 A cluster map of the soil chemical data (ratio level) of the test site on ordinal level

Using the nominal data, borders were defined by search for spatial, rather statistical clustering. To do this we superimposed a 123x242 grid (cell size is 50x50 m) over the study area using Arc/Info 7.0.3. software. The result, however, is different depending on the applied method, but we have got very low number clusters, which consisted only few elements. For example we obtained only five classes of more than 10 pixels (58, 37, 24, 12 and 10 pixels). But these clusters were only a small portion of the 14,360 pixels — cover the watershed — in the grid. As we saw above, on this level all the advances disappeared which were useful on the ratio level. Therefore, we have had no chance to explore new relationships, because only few parameters (7) were used and only two ordinal cluster maps with too many classes.

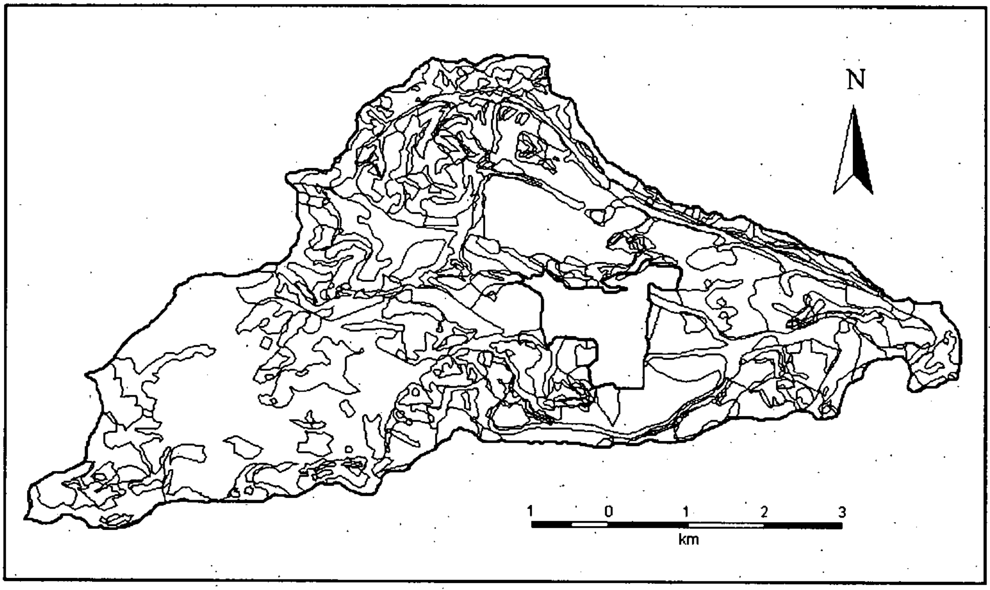

Figure 4 Statistical units of the landscape

Since our aim was to explore the topology, it seemed easier to analyze all the input data on the nominal level. We aimed not to do any weighted during their selection, thought the selection itself is a kind of weighted as far as we have had to consider whether to use a certain parameter or not. The analysis made on the ratio and ordinal level helped us to decide which parameter should we take into the analysis. As an attempt we created two parameter sets. Into the first one three parameters fall: soil texture, land use and slope categories; the first one carried the information of the ratio level, the second one represented the nominal, while the slope categories carried the ordinal information. The second parameter set included soil texture, land use, slope categories, thickness of the tilth, soil pH, vegetation type, exposure and diversity of vegetation.

The maps of the different sets of variables were overlaid and compared using the polygon-intersection method available in Arc/Info software. The first, smaller set of variables yielded the following results. The 9 categories of the soil texture map produced 70 polygons, the 8 categories of the land use map produced 52 polygons and the 5 categories of the slope categories produced 316. The intersection of the resulting maps produced 1130 polygons (*Fig. 4*) each of which is homogenous from the standpoint of some combination of the three variables. Altogether there were 15 distinct combinations, 7 of which together covered more than 80% of the area (*Table 2*). The remainder of the area differed only by soil texture, the first variable (*Fig. 5*), not by land use or slope. This remained the case even after the number of slope categories was increased using a more detailed scale.

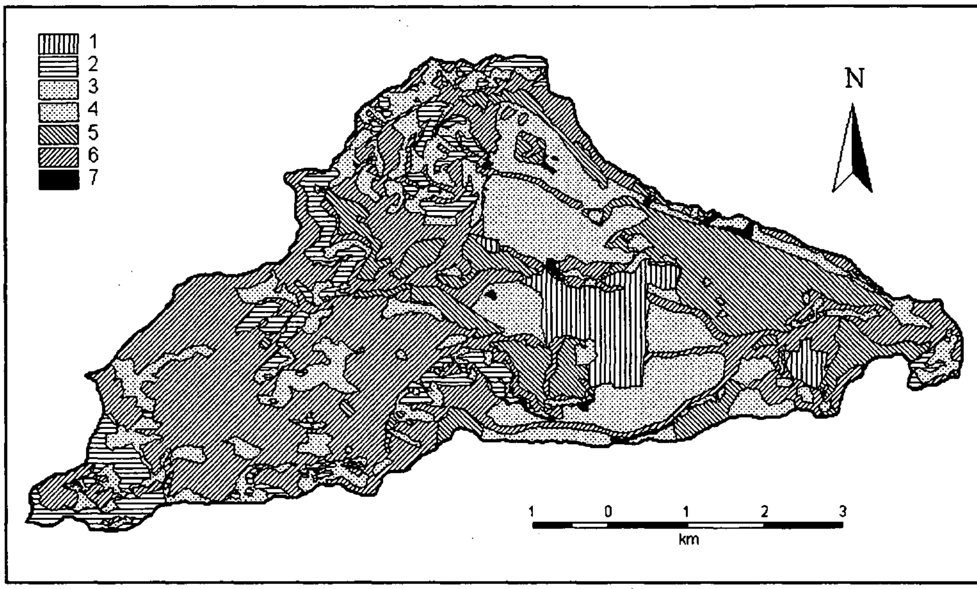

Figure 5 Polygons resulted by the intersection of landuse, soil texture and slope category maps (**1**: 0-12% slope angle, downtown, lake, quarry, loamy silt; **2**: steeper slope than 17%, meadow, forest, silt; **3**: 12-17% slope angle, meadow, pasture land, grove, clay; **4**: 0-12% slope angle, arable land, silt; **5**: 0-12% slope angle, meadow, pasture land, clay, heavy clay; **6**: 0-12% slope angle, forest, sandy silt; **7**: steeper slope than 12%, arable land, clay)

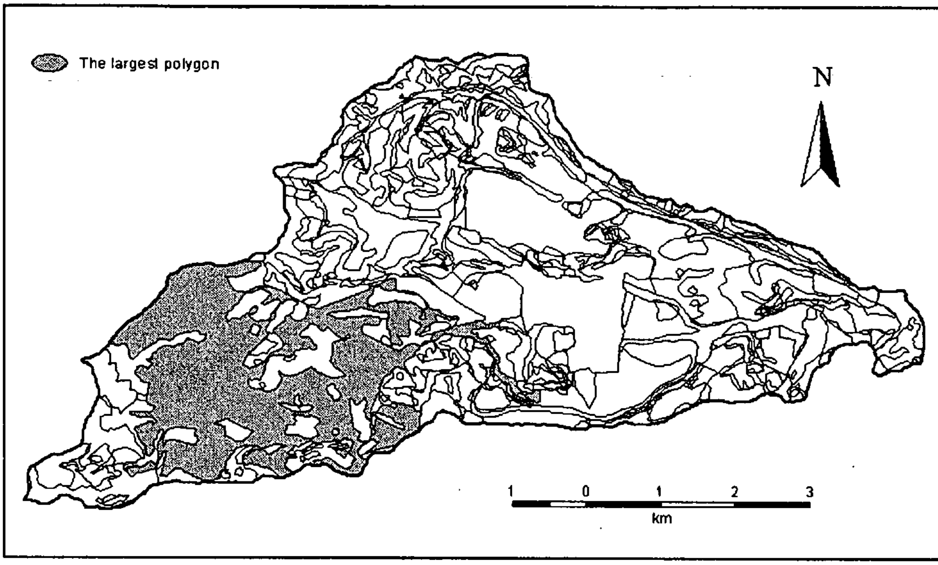

Figure 6 The largest polygon produced by the intersection

From the ecological point of view, we think it is very informative to examine the characteristics of the spatial clusters. The total number of polygons gives an overall sense of the mosaic-like structure of a landscape, their average size provides a sense of the relevant scale, and the largest polygons (*Fig. 6*) provide a sense of the most homogenous characteristics.

It is worthwhile to compare these results (*Fig. 5*) with a traditional geoecological map of the same area produced by Mezősi and Rakonczai (*1997*) (*Fig. 7*). The comparison was made by cross-tabulation and can be considered from two perspectives. The first is whether the statistically defined categories match those of the traditional ecological map, and second, the degree of this correspondence. Those categories that coincide by more than 10% are listed in *Table 2*.

The table indicates that only a few of the categories (1, 4, 6, 12, 14 and 15) of the two maps coincide by as much as 75-85 %. Closer examination reveals that survey categories 1 and 15 are both contained in statistical category 1, survey categories 4 and 6 in statistical category 6, survey category 12 in statistical category 5, and survey category 14 in statistical category 4. There seems to be no relationship between the size of the categories and the degree of correspondence between the two maps. Survey categories 1 and 15 are urban areas with the ecological characteristic of settlements. Their distinctive characteristics and high spatial concentration can be seen in the statistical map as well. Survey categories 12 and 14 are also distinctive and not unexpectedly appear as different statistical categories.

Category 12 includes xerophilous steppe meadows, whereas category 14 contains arable land. The meadows are typically found along ridges whereas the arable land usually occupies the middle part of the drainage area, at mid-elevation, and on relative low slopes. It was not surprising that survey category 4 also appeared strongly in the statistical map since it corresponds to swampy and marshy stream valleys covered by hygrophyte forests. At first it is difficult to explain why the small survey category of Scotch pine forest falls into the same category as swampy and marshy land. Forestry data indicates however that the Scotch pine forest plantations were based on economic (easy accessibility, low relative relief), rather than ecological considerations.

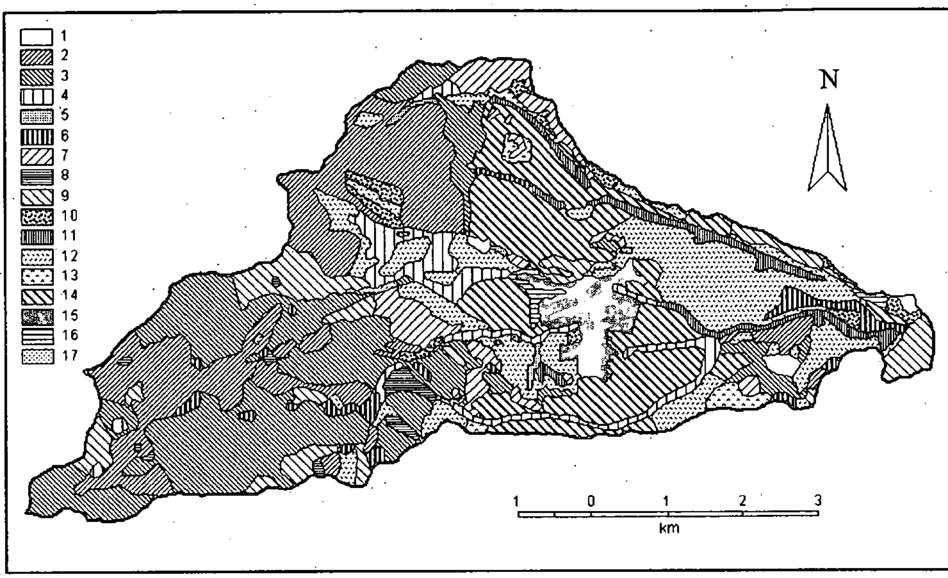

Figure 7 Landscape ecological map of the model area made by field survey
1 - settlement, quarry; 2 -mesophyl deciduous and mixed forest on sandy soil, on slopes steeper than 12%; 3 - xerophyl groves, bushy associations on slopes steeper than 17 %, on silty soil, pasture land; 4 - swamp, hydrophyl forest on silty soils, meadow; 5 - hydrophyl groves; 6 - Scotch pine plantation on clay; 7 - deciduous forest plantation on silt, on foothills; 8 - young deciduous forest plantation on sandy silt, in valleys; 9 - planted mixed forest mainly on sandy soils, on slopes steeper than 17%, east exposition; 10 - bushy associations on hills, on silty soils; 11 - vegetation of eutrophic waters and springs, pasture land; 12 - calciphylous meadows on loamy silt; 13 - ruderal and weedy meadows on loamy silt; 14 - arable land on slopes 0-12%, on silty soils; 15 - small gardens, parks; 16 - orchard, fruit plantations; 17 - vineyard and hop plantations on slopes 12-17%, on loamy silt

These results of this comparison indicate that six of geoecological categories (*Fig. 5*), representing almost 40% of the area, are homogenous and well-defined. Of the remainder, geoecological categories 2, 3, and 9 are non-homogenous, composite categories that are definitely not well-defined.

Viewed from another perspective, *Table 2* also shows that statistical category 6 contains a great number of the survey categories found on the traditional geoecological map. This implies that this category is overclassified under the traditional survey method, that is divided into more categories as are supported by the present statistical analysis. Part of the difference may be accounted for by the fact that the survey was based on field investigation in which a uniform geoecological category was further subdivided by vegetation type.

Categories of the landscape ecological survey's map (see their description on Fig.7.)	Number of pixels covering each category of the landscape ecological map	The percentage of pixels in each category of the landscape ecological map that coincide with the categories of the statistical map (Fig. 5.) (only those values above 10% are listed)		
1.	319	90 % (1)		
2.	2379	53 % (6) *	27 % (3)	19 % (2)
3.	3268	66 % (6)	19 % (3)	13 % (2)
4.	687	82 % (6)		
5.	49	67 % (6)	14 % (5)	12 % (3)
6.	330	79 % (6)		
7.	648	65 % (6)	20 % (3)	13 % (2)
8.	121	48 % (6)	28 % (3)	23 % (2)
9.	944	53 % (6)	28 % (2)	17 % (3)
10.	274	71 % (6)	27 % (3)	
11.	376	63 % (5)	33 % (6)	
12.	2165	85 % (5)		
13.	163	60 % (4)	36 % (6)	
14.	2315	88 % (4)		
15.	217	81 % (1)	15 % (4)	
16.	92	67 % (1)	25 % (4)	
17.	19	63 % (1)	21 % (3)	

Table 2 The correspondence between the landscape ecological maps made by land survey and by statistical analysis (* 53 % of the 2379 pixels belongs to category 6 of the statistical map, 27% to category 3, and 19% to category 2)

It is worthwhile to compare the statistical map categories with the borders of the geoecological map (*Fig.1*). We found, as expected, few areas of correspondence between the traditional survey and the statistical maps. This was not surprising because the parameters used to produce the geoecological maps (such as run-off regulating function, soil erosion) are interrelated and determined primarily by relief. Still, this should not be viewed as a flaw since the geoecological map contains much information of practical value. It means only that the statistical map delineated borders using strict criteria. The geoecological map was compiled to reveal, as possible, hidden or obscured attributes of the landscape units. Such subtle gradations appear in the statistical map only when characteristics like soil erosion are determined by cross-classifying a wide range of factors. Such subtleties can be noted, for example, in statistical category 6 which corresponds to areas of moderate run-off regulation function, poor agroecological potential and moderate soil erosion and in statistical category 4 which corresponds to heavy soil erosion, moderate agroecological potential and moderate run-off regulating attributes.

The most important warning indicated by our findings is that, in landscape ecological research, special attention must be paid to the selection and analysis of variables and their statistical type. Their use must be planned consciously to serve the aims of the study and must take into account the statistical rules that govern their use. But methods exist for meeting these rules of spatial statistics in the analysis of many types of complex landscape ecological maps.

Conclusions

1. In some cases, the landscape units used in landscape ecology are not well defined mathematically and statistically. That is, from time to time, the landscape units cannot be differentiated one from another strictly in terms of their underlying statistical distributions. Sometimes too, the underlying statistical distributions are used incorrectly in defining the landscape units.

2. There are nonetheless several statistically correct solutions for delimiting the landscape units if needed. This does not mean that they are the only units that should be employed. There are other such landscapes units that are used in practice and derived from other principles such as the weighed of selected variables. These may work well if they are designed carefully. The variables that are included must be selected and controlled with care. Statistics can be an effective tool of analysis, but it cannot be used automatically to solve all problems.

Acknowledgment

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GEYSER REMNANTS IN THE GRAVEL PIT AT LESENCETOMAJ

Pécsi, Márton – Kiss, Tímea

On the north-west margin of the Tapolca Basin a gravel pit was established at Lesencetomaj on the pediment of the Southern Bakony. Here the 8-10 m thick gravel bed consists of several passegeway-like forms of former geysers.

The origin and the stratigraphic situation of the gravel bed – sometimes called "Billege gravel" – is not clear yet. Several scientists made an effort to solve this problem:

- According to Sümeghy J. (*1953, 1955*) and Góczán L. (*1960*) these gravels represent the direction of flow of the ancient Danube. This could be proved by their sphericity, that is similar to that of the gravels' of the Danube, though, their mineralogical composition is different.
- Another possibility is, that it is the eroded material of an older formation, which included several gravel generations – the Oligo-Miocene gravel cover of the Bakony Mountains – and was transformed by abrasion (*Jámbor Á. – Korpás L. 1971, Juhász Á. 1970, 1974 and Jámbor Á. 1980*).
- Bartha F (*1959*), Szatmári P. (*1971*) and Jámbor Á. (*1980*) classify this layer as Lower Pannonian.
- Nobody has found basaltic gravel among the gravels, therefore, it is very probable that it was accumulated before the beginning of the basalt volcanic activity (*Pécsi M. 1975*).

Description of the exposure

During the operation of the gravel pit two easily distinguishable layers were brought to sight: the lower one is approximately 8-10 m thick, and consists of very well rounded gravels. These gravels have an iron lining and at some places they are cemented. The gravel beds show an inclined stratification. At some places we have found passageway-like forms filled with sand (*Fig.1*). The gravels on the border of the sand and gravel have different orientation: they are standing upwards bedding into a weathered material. The light greyish sandy filling is loose, and it indicates an intensive upward movement. On the top of the gravel bed this sandy filling ends in a flat cone with mild slopes. The gravel layer and the sand humps are covered by sandy gravel.

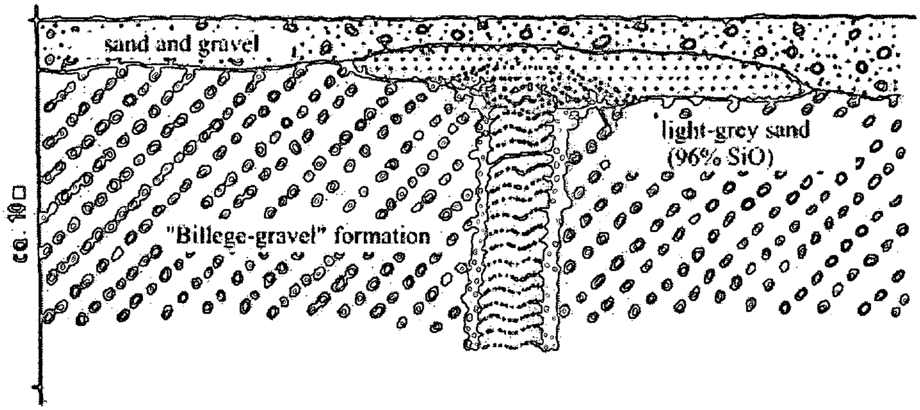

Figure 1 Passageway-like forms filled with sand

Possible explanation of the forms

The passageway-like forms in this gravel pit indicate the postvolcanic activity of the basalt volcanism, since they are the remnants of former geysers.

The sand in the passageways originates from the Pannonian sandy bed, which is situated under the gravel deposit. Probably the water of this Pannonian sandy sediment supplied the geysers – as it is indicated by the sand filling in the passageways and by the sand cones on the former surface, though in other places the passageway is filled by pure silica. Due to the violent upward movement the gravels in the walls of the passageways were moved, their original orientation had changed and adequately to the convection of the overheated water they were oriented upward. The walls of the passageways were lined with sinter, which has been weathered since its formation. The cone over the passageway consists of weathered material as well (96% silica). In Iceland the Great Geysers consist of 84,4% silica, while in the Yellowstone National Park, in the Upper Geyser Basin 95,8% of the sinter is silica (*Balogh K. 1992*).

The activity of the geysers was probably in connection with the basalt volcanic activity of the surrounding area. This volcanism had started in the Pontusian Age and it lasted until the end of Pleistocene. On the territory of the Bakony Mountains there were about 40-50 volcanic centers: according to K/Ar datings ((*Balogh K. et al 1982*) the volcano of the nearby Haláp erupted 2,63±0,3 Ma ago, and the St. György Hill was formed 2,8±0,33 Ma B.P. The older basalt volcanic activity (at Tihany 7,0 Ma B.P.) was followed by postvolcanic activity too, that formed the hydro-quarzite cones of the Tihany Peninsula. Here – in the Aranyház – quarzite gravels are cemented by hydro-quarzite, therefore, it is very probable that the dozens of passageways in the Lesencetomaj gravel pit were formed the same way as the hydro-quarzite cones at Tihany.

The longlasting postvolcanic activity appeared not only in the form of geysers and fumarolas but in other thermal features like travertine as well. Where thick limestone bed was under the surface, the rising warm water dissolved and brought up enormous quantities of calcium carbonate to the surface and created tuff terraces. Such travertines of thermal origin can be found on the Balaton Upland (T10 – *Pécsi M. 1987*), in the Gerecse Mountains at Kőpite (T9 – *Scheuer Gy. – Schweitzer F. 1981*) and on the Terrace V. of the Danube, where the gravel deposit is covered by pipelike-structured travertine.

Contemporary analogies of the forms

Similarly structured features can be found in the Yellowstone National Park. Here the material of the geysers – the dissolved silica – originates from the rhyolitic rocks, 60-70 m below the surface. The hot water carries the dissolved silica through a cemented sand and gravel bed, that was deposited by glaciers. The hot water is stored in the lenses of this sediment, and it gets onto the surface through a passageway, which is lined with sinter. Since the dissolved silica precipitates both above and below the surface, sinter could be formed both in the plumbing system and on the surface in the form of cones as well (*Harris A. – Tuttle E. 1995*).

Besides geysers and hot springs, travertine also forms in the Yellowstone Park: not far from the world's largest travertine forms (Mammoth Hot Springs) geysers and fumarolas can be found in the Lower Geyser Basin, just 45 km faraway.

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POSSIBILITIES PROVIDED BY GIS IN THE EVALUATION OF LANDSCAPE CHANGES ON PLAIN TERRITORIES

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Introduction

Natural and anthropogenic factors have caused significant landscape changes in the previous centuries. There are several tools to examine these (archaeological information, historic documents, comparison of maps, measurements and statistic evaluations based on these, remote sensing, monitoring, etc.), as we have summarised it detailed in a previous study (*Rakonczai, J. 1988*). These methods are adequate to carry out general analyses, but they are hardly proper or rather improper to evaluate the quantitative changes of the landscape. This problem is especially true in case of plain territories, where there are hardly any points that could be used for reference during evaluation. Hence, those examinations are of great significance that can enable the exact spatial and quantitative evaluation of previously recognised qualitative changes, since, that is how these changes become useable for practical purposes, and authentic for science. The application of GIS provides quality solutions in this field. GIS makes possible to compare formerly separately handled, very different spatial data systems, thus, it may widen the ways of the application of classic methods, too.

Nowadays, there is an increasing practical and scientific demand to determine both the qualitative and quantitative characteristics of landscape changes. Although, landscape development itself can be observed even during a lifetime interval, until the present we could not evaluate relatively small degree annual changes in a quantitative sense. Consequently, there are two opportunities to provide an answer for widened scientific demand during evaluation: on the first hand to improve considerably the precision of analyses, on the other hand to extend the time of investigation. The improvement of geoinformatic methods provides us a chance to widen our scientific interest in both directions: the development of remote sensing, land survey and other techniques increases precision, while the ability of systematising different data bases may ensure the temporal widening of the examination.

The aim of the long-term research that is set forth in the present study is dual. Partly to determine from a methodological point of view how and in what degree can data originating from different periods and from different sources (old maps, topographic maps, airphotos, satellite images) be integrated into a unified information system (at the same time this may give an opportunity to the significant temporal extension of authentic environmental evaluation). Partly, on the basis of relevant data, and information that were transformed into a unified geometrical system, we have been to determine certain landscape changes that later can be applied in the environmental, conservation practice as well.

- The circumspectly chosen studied area, that is a part of the Kiskunság National Park, is located on the territory of the Danube-Tisza Interfluve (*Fig. 1*).

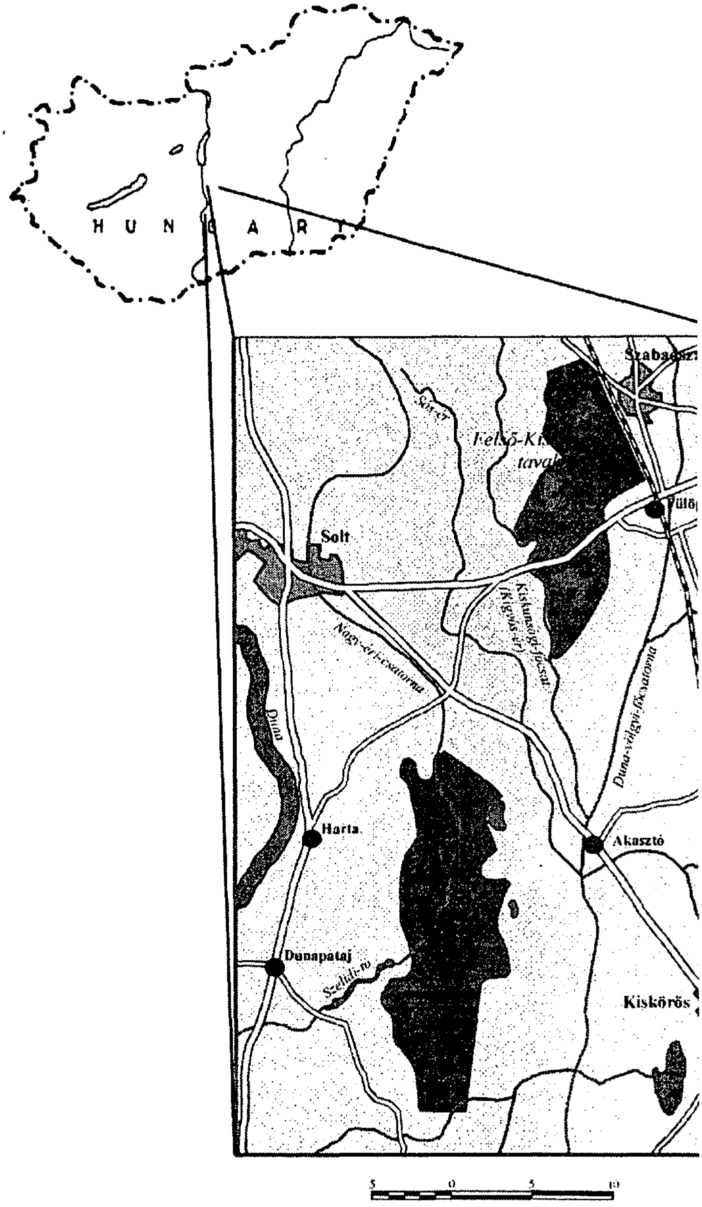

Figure 1 The study area

Here, at the beginning of the research three geographical, ecological problems occurred that seemed to be answerable with the help of GIS. These are the following:

- Soil erosion processes (sodic bench erosion) that can be inevitably detected on the territory of low relief. The measuring of these only with traditional methods would provide considerable errors due to the relatively short period of measuring.
- The water household of the territory was significantly modified by the hydrological changes that followed the water regulations, then by the increasing utilisation of water resources, and currently by the presumed global warming. Maybe the most notable results of these processes are the decreasing water surfaces, and the disappearing, formerly typical, sodic lakes.
- As an unfavourable ecological result, the invasion of weed associations endangers wet land habitats of the anyway decreasing water surfaces and their vicinity. The exact temporal and spatial evaluation of these processes with traditional methods is not only difficult, but uncertain at the same time.

Relevant stages of landscape evolution on the studied territory

The territory, located on the 20-25 km wide Danubian Plain, lies just 4-5 m above the former low water level (characteristic before the flood control operations on the Danube), thus, it is not surprising that due to frequent floods the lower floodplain was regularly inundated by water. The ancient water system was characterised by depression (acting as swampy, marshy territories of poor drainage) that were surrounded by levees, representing the higher flood plain level (point bars, dunes and alluvial fan territories). Due to the limited possibilities of outflow, the water leaving the river remained on these territories for weeks, months, and became pan water, therefore the region had been one of the richest territories of the country in standing waters. We must consider that there had already been sodic areas formerly, but then the evaporation of the waters and the high level and low gradient of the ground water provided adequate conditions for further sodic processes.

The major consequences of human activity on the territory are due to flood control operations. The regulation of the wild world of the Danube floodplains was started with the cut of the river bends, the construction of dams and the Duna-völgy Canal (1914-1930). *After the regulations the territory dried out*, and only on the deeper, shallow areas did swamps of temporary water level remain. Parallel with this, rapid sodification of soils and development of secondary sodic areas became characteristic as well. Documents of preceding times also prove that the extent of ancient sodic plains had not been at all as large as in the era following the 1930s. The set of anthropogenic influences was completed with the spread of extensive animal breeding. The result was a sodic plain with extreme water household and solonchak type soils. It was characterised by sodic reeds, marshes with Bolboschoenus maritimus and extremely sodic patches.

Since, nowadays the dams impede floods, *the eroding and accumulating effect of the Danube is not apparent either*. Thus, the region has become a flood free plain with a poor drainage that have resulted in the development of numerous sodic meadows. Due to the increasing anthropogenic influence the territory have gained a culture-steppe character (*Marosi, S – Somogyi, S 1990*).

The base of geoinformatic analysis

The major data sources were: *maps covering a two hundred year period, airphotos, satellite images and field work.* After time-consuming preparations all these were composed into one *unified system*, which enables comparisons.

The I. Military Mapping, made in 1783, represents the original natural conditions with 1:28,800 scale. Naturally, the methods of mapping were simple – not even triangulation was applied – hence, the data on these provide just rough information. The subsequent studies on the conditions of the mapping (*Biró, M. 1999*) showed that the maps' quality greatly depends on the person who compiled them, their correctness is questionable, therefore, the borderlines on them have only an informative character, or they can be applied only after further, detailed investigations. The regulation works on this part of the Danube started much later, the region was characterised by regular floods, and among the natural conditions, maintained by the river, the identification of fix points is very difficult.

The II. Military Mapping was carried out in 1852, still with the same scale, but with improved methods. The III. Military Mapping, that was made 30 years later, resembles the changed conditions caused by flood control, with a 1:25,000 scale. The mapping was carried out after the regulation of that part of the Danube that is crucial regarding the studied area, thus, it provides several pieces of information on the transformed ways of land-use.

The topographic maps of 1:10,000 scale, made in 1961 and 1981, applying stereographic projection and EOV co-ordinates, show the effects of excess water regulations. Considering their scale, correctness, and content, the most information can be obtained from these.

Another group of sources are the photos taken by remote sensing: black and white airphotos (early summer of 1950, April 1973, August 1994 – the seasonal differences made correct comparisons very difficult), their approximate scale is 1:10,000 and 1:25,000. The obtained multispectral Landsat TM photo was made in the middle of April 1997.

In order to determine bench development processes in the future, we made GPS measures, which were complemented with data provided by field geodesy. (We are going to control these results in every five years.)

Methods of geoinformatic analysis

In case of the Northern Kiskunság and Miklapuszta the first task was to *process the data sources with different scale and projection, from different times in a way that our next aim, the appraisal of data on the landscape development of the territory could be carried out* (i.e. it is important that the data can be *examined independently, but at the same time they can be compared and converted, too*). To carry out this aim, we had to transform different data models of different scale into one system – in our case logically into the EOV Projection System. The processing of raster and vector data was made under *ERDAS Imagine* and *Arc/INFO* softwares, respectively.

Geometrical correction ensured that all of our raster and vector layers contained the co-ordinates of the chosen projection system. The process itself is a projection to plain, through which the data are ordered to a map projection system.

The processing of raster data starts with the searching for well identifiable surface control points both on the maps and the photos. This is called the "image to map" method. The annual and seasonal change, that especially characterises sodic areas, made this difficult. Due to the low number of points, we carried out first order, occasionally second order transformations. After correcting our maps one by one, we chose the "nearest neighbour principle" to resample them. Only in case of the satellite image could we apply the quicker, "image to image" correction method.

During the analyses of maps the shorelines of lakes, roads, and rims of sodic bench were digitised as vector layers. When transforming vector data, we had to *convert three different scales and four different projections into the EOV system*. During digitising the so-called TIC points were obtained from intersections that can be exactly identified both on older and newer maps as well. After determining the corrected values of these points the whole vector layer was placed into a frame marked by these. The overlapping of the transformed layers and their comparison with airphotos, corrected with other methods, proved the correctness of the applied method.

The airphotos having EOV values and the satellite image made it possible to determine the boundaries of water surfaces showing unambiguous changes. After all, we gained 8 vector layers to evaluate the hidrogeographic development of the territory from 1783 till nowadays. The airphotos, thanked to their resolution, provided additive information concerning the rims of sodic benches.

After the multispectral processing of the Landsat TM image, beside the visual display in different band combinations (RGB, 321, 453, 742), with the help of digital image processing we made a Normalised Difference Vegetation Index (NDVI) map, and by automatic classification land-use maps were produced as well. The objective results of these provide further bases for oncoming investigations.

Results

Experiences in connection with the establishment of a unified data base

The geocoding, that is necessarry for processing data provided by remote sensing and maps, beside the fact that it is the most adequate for establishing a unified data base, is the first step in the complex geoinformatic analysis. The geocoding proved to be suitable for processing data of different character into a uniform system. The fitting of the layers was excellent, thus, we were able to increase the length of examination period beside preserving the precision of measuring, and it enabled the evaluation of field survey as well. However old a map was, the spatial correspondence appeared correct on all layers.

Regarding especially the sources of the 18th but that of the 19th century as well, the natural conditions of the plain like territory made it difficult to find permanent control points, that would help in the evaluation process. (As we have seen before, even the subjectivity of the surveyor left its mark on the military mappings). In case of the airphotos, the seasonal differences occurring at photographing made the evaluation more complicated. We have found that due to the character of the investigation the major data source of the continuous observation must be air photographing. *According to our experiences gained during the* *analyses, in order to monitor correctly the wetland habitats, detailed air photographing would be necessary at least in every five years.*

Naturally, satellite images may get an important role in the evaluation of landscape, but their resolution is not adequate to analyse local and micro-processes.

Although the geometrical correction does not always provide complete 100% correspondence when mosaicing the different images, it have become an inevitable tool in the objective surveying of landscapes. The establishment of the system is a long process, requiring diverse technical equipment, but the subsequent actualising and enlarging is easier and faster.

Measurable landscape changes in the past two hundred years:

<u>The change of Northern Kiskunság Lakes</u>

The hidrographical changes on the territory have several manifestations: great decrease in the number of lakes (concerning this problem the Headquarter of the Kiskunság National Park has made overall investigations), decrease of water surface of larger extent, and the pervasion of harmful plant associations at the expense of open water surface.

In our case the open water surfaces of a territory of an approximately 11 000 ha size were examined. The size of constant water cover decreased to 16 % from the 18th century till 1994 – naturally, the greatest decrease was due to the excess water regulations after the III. Military Mapping. (At the end of the 1990s, as a result of some wet years, the extension of water surfaces have increased, but very likely this positive change is temporary). The effect of the past 40 years is also significant. During this period, according to the airphotos, the invading weed associations advanced 310 - 350 m – with the strengthening of this process the "puszta" becomes more and more poorer concerning the number of species (*Kalotás 1996*). By knowing the tendencies of the disadvantageous years, it is to be feared that *further 60-70 years will be enough for the complete disappear of open water surfaces.* A good example is the Kisréti Lake, that formerly was the largest standing water here, but now it hardly has open water surface. Its southern neighbour is the Zab-szék Lake, that can be considered the most stabile lake on the basis of its present area, contour, and ecogeography.

Statistically, the airphotos represent an average 1% annual decrease in the water surface. The above mentioned Kis-réti Lake is unique in this sense, since in the past 44 years with its annual 2% surface decrease it has shrunk to a portion of its former size. On the contrary, in case of other larger lakes the degree of change has decreased 50 % since they were declared protected in 1973.

The data obtained from earlier maps differ to some extent from the data of the past few decades. During the examined two hundred years the characteristic pace of decrease was 0.1-0.5 % per year, and it was just occasionally interrupted by advantageous changes. (In case of the Kis-réti Lake the process is more intensive, here the starting surface was 2-3 times larger than the present one.) As we get closer to the present each lakes' surface inevitably started to decrease, e.g. the most changing lake the Kelemen-szék lost most of its open water surface in the past 20 years (*Fig. 2*). *After all, the surface-decrease deduced from the interpreted values is larger than it can be expected from data provided by maps!*

Botanic analyses also support the fact of decreasing water supply in the region. The drying process at Miklapuszta, but on the whole territory as well has had more stages: (1) the swamps sustained by floods and (2) the excess water turned to be sodic marshes, (3) then they gave their place to sodic meadows, (4) on which steppe formation can be observed (*Horváth 1997*).

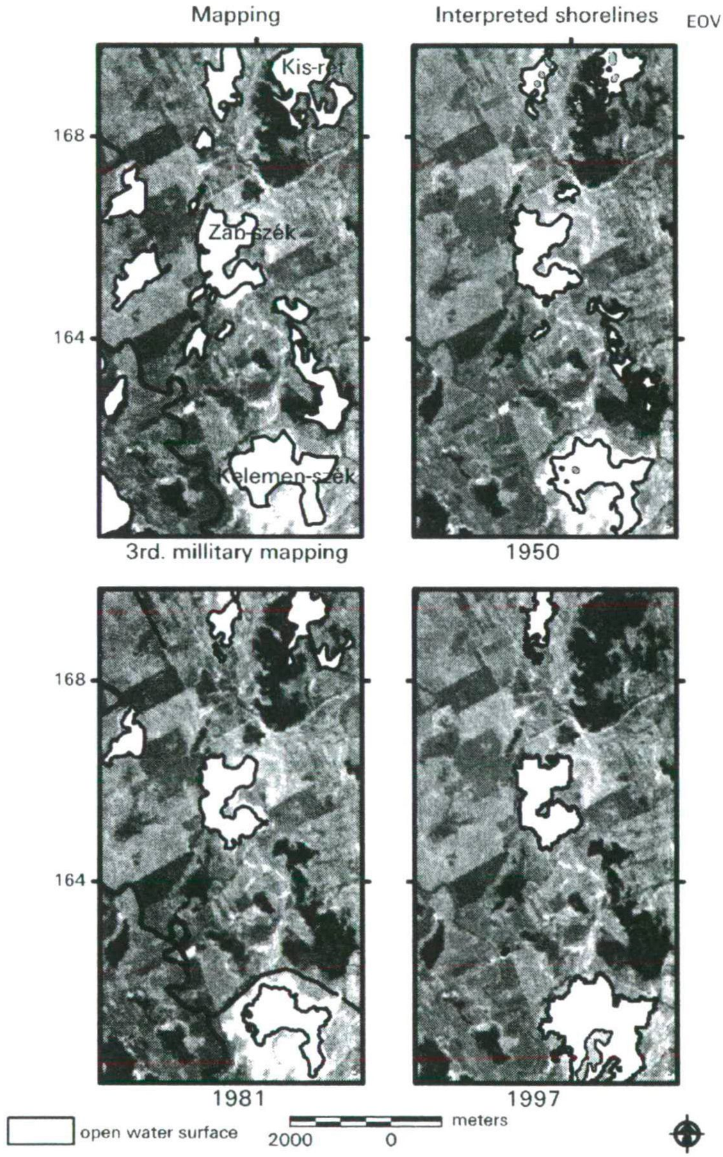

Figure 2 Hidrographical changes of the lakes in the northern Kiskunság (the background is a Landsat TM satellite image)

Geomorphologic analyses

The height of sodic benches (80-130 cm) on the territory of Miklapuszta, made up of solonchak type soils, is outstanding in Hungary. The established data base made possible to determine the rate of retreat in terms of sodic bench rims (a typical form of soil erosion on plains). Based on the comparison of the III. Military Mapping with the combined maps and airphotos from the 1961-1994 period, we got the approximate erosion of a hundred years. *The gained 20 m/100 year mean value supports our former assumption that annually even a 15-30 cm retreat can be observed.*

From the 516.88 ha territory involved in the detailed analysis, 25.38 ha, i.e. almost 5 % of the surface, had eroded during 80 years (1882-1961). Even by assuming just a 50 cm average height for benches, this means the erosion of 127 000 m^3 (!) material, that is equal to 1600 m^3/year, and 3m^3/year/ha values.

Concerning the actual rate of surface erosion this value can serve as a minimum, since the average benches are higher, and the uncertain territories were not involved in the evaluation. (Since 1997 we have carried out GPS measurements on the territory in order to determine the present rate of erosion. For more exact evaluation we suggest a 4-5 year periodicity in remeasuring.)

Detailed examinations also point at the causes of erosion, e.g. herds have a great role in the dissection of uniform benches, and along their major routes – around watering places, wells – rills can be noticed on the surface of the benches. The mapping of roads used by vehicles is difficult because car-tracks can be found all over the plain. Due to the temporary marshy character of the territory the real roads run mainly at the base of the benches, thus, they greatly increase the rate of erosion. The process is especially characteristic in the vicinity of agricultural lands, where the tractor-tracks and vehicle turns noticeably have a great effect on the surface. Due to the quality of soil, the accumulating and water collecting effect of the tracks running through sodic meadows gives a linear structure to the vegetation (*Fig. 3*). The effect of tracks made by one but heavy vehicle can also be observed, even after they were covered, too! Narrow ditches running along the plain, serving the faster drying of the territory, close to the benches also take part in the degradation of the soil cover. As an anthropogenic effect, also along roads, cattle tracks and ditches there is an increased erosion where deepening occurs. That is why Horváth, A (*1997*) suggested that it would be desirable to forbid car traffic and restrict the grazing of cattle on the territory.

According to our experiences, the degree of degradation significantly depends on the length of the rim that can be attacked by erosion (*Fig. 3*).

These draws the attention to the danger meant by newly (last few decades) established roads and ditches, that increase erosion by providing further attackable surfaces. Based on the analysis of airphotos, the severe problem of desection of the territory is inevitable (*Fig. 4*). Since, long ago we have done the first steps toward launching sodic bench erosion, that is very hard to stop, it is not difficult to predict that this valuable landscape of ours is going to disappear.

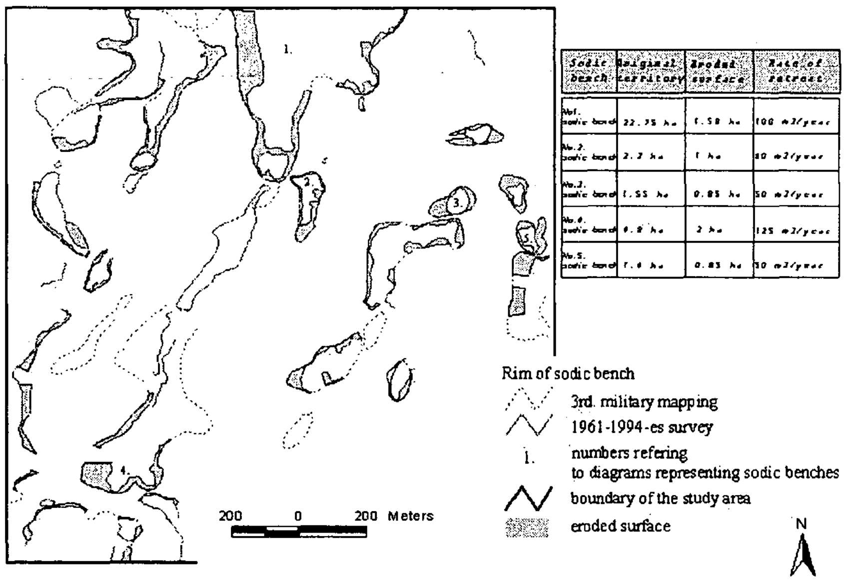

Figure 3 Rate of sodic bench retreat at the northern part of Miklapuszta

Based on our pragmatic investigations, a question arises: how could more than a hundred thousand m^3 material left the territory? Although, there are documents proving that a considerable amount of native soda was collected and taken away from panned waters of the territory at the end of the 19^{th} century, we assume that aeolian activity played the major role in transportation.

Conclusions

During our research we managed to establish a data system that made the evaluation of landscape changes – two hundred years retrospectively – possible even on a plain territory with relatively few TIC points. With the application of this system the evaluation of geographical processes can support the realisation of practical tasks as well. In addition, it provides a chance to predict the future occurrence of negative processes that require intervention.

On our studied territory the greatest environmental problem is the withdrawal of water surfaces and sodic bench erosion. The previous one can be solved by keeping back water or by supplying the territory with extra amount of water (this must be complemented with the repression of harmful vegetation). To treat the other, drastical land-use restrictions would be necessary (on vehicles, grazing, construction of linear establishments), but still, these would only have limited results. After all this implies that environmental protection should not remain on the level of using passive methods on the territory.

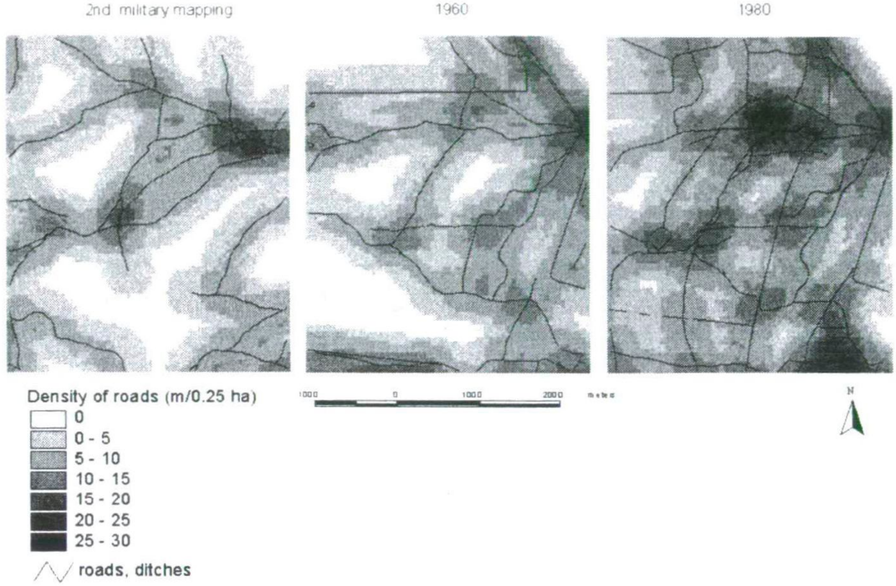

Figure 4 Change in the density of roads on the northern part of Miklapuszta

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LAND USE CHANGES ON THE HILLSLOPE OF THE FEKETE HILL (KÁLI BASIN) BETWEEN 1958-1993

Szilassi, Péter

Introduction

The aim of the historical ecological investigations and landscape history is to obtain information on the changes of the landscape structure and land use, and to collect a database for planning landscape reconstruction and landscape rehabilitation. Most of the researches dealing with this field have made endeavour to study as long periods as possible using the first, second and third military mappings (*Gábris Gy. – Miczek Gy 1999, Csemez A. 1999*). The most pronounced element of landscape changes, which can be presented on maps easily, is the alteration of land-use. In this paper the author presents the results of a study dealing with those changes which influenced landscape development on the Fekete Hill in the recent past.

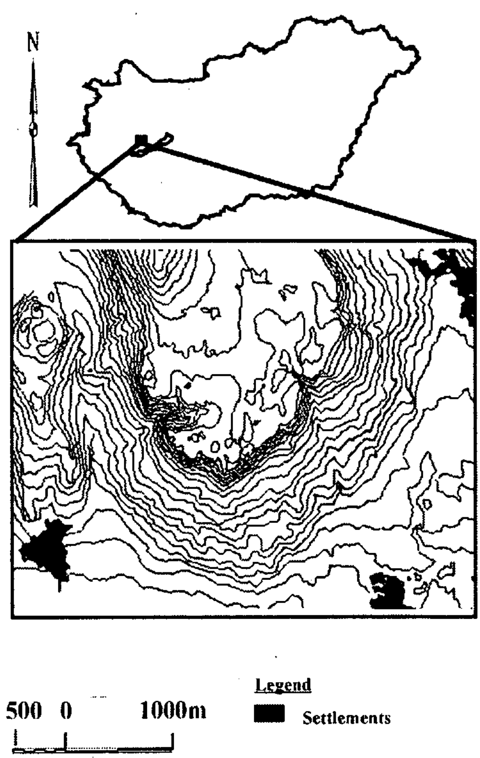

Figure 1 Topographical location of the study area

Aims

The study area belongs to one of the small basins of the Balaton Upland – the Káli Basin – occupying its northern part (*Fig. 1*).

The Fekete Hill is one of the remnant hills of the basalt volcanoes of the Balaton Upland. On its slopes viniculture has been the traditional way of land-use since the Roman Times (*Böhönyei Á. – Szantkuty G. 1982*). The aim of our study is to describe and evaluate the spatial and temporal changes in land use during the last three decades on the slopes of the hill. This paper studies only two ways of land use: vineyards and forests. The area is under protection since 1984 and it is part of the Balaton Upland National Park since 1997, these facts gave motives for the research. The aim of the National Park is not only the protection of natural values, but the preservation of the traditional ways of land use as well (in our case the viniculture). Therefore, it is very important to reveal the characteristics of landscape evolution, and in this way to get data for future landscape reconstruction.

Methods

For the evaluation of changes on the territory of vineyards and forests, airphotos (1973, 1984, 1993) and topographical maps with 1:10,000 scale (1958-, 1979) were used. The airphotos and maps therefore represent five dates. We have transformed them to the EOV system by using ERDAS Image 8.3 software. In this common system we have outlined the different land use types on the maps and photos, then we made a digital thematic map. The resulted borderlines of the land use patches were overlapped by ARC/Info software. As a result, we got spatial data on the different types of coverages by using a 10x10 raster-web. The result of cross tabulation of the thematic raster map was a table showing the degree of changes between two or more dates. We constructed a table of these results showing the changes in „ha" or in percentage of the whole territory.

Results

Analyses of spatial changes in land-use

Comparing the 1958 and 1993 extent of vineyards and forests (*Fig. 2-3*) it can be seen that the changes concerning these two ways of land-use are different in sign and in space.

The territory of vineyards has decreased considerably and they remained on the lower parts of slopes, but at the same time the size of parcels decreased. This spatial redistribution can be explained by social reasons:

- The population of the villages around the Fekete Hill (Balatonhenye, Köveskál, Szentbékkálla) has been decreasing since the 1960s. Their age structure is becoming less and less favourable: the percentage of people older than 60 years is far higher than the Hungarian average (*Szilassi P. 1999*). Therefore one explanation for the transformation of vineyards, is the unfavourable age structure and the transmigration, i.e., less and less local citizens can cultivate their own land.
- The other reason of the dramatic decrease of vineyards is in connection with their changing ownership. The Káli Basin is part of the Balaton Recreation Zone, where the recreational function has become more important since the beginning of the

1970s. The vineyards were bought by citizens of the neighbouring towns (e.g. Tapolca, Veszprém) and of Budapest. The new owners are giving up the laboursome viniculture for horticulture, or they leave their lands uncultivated. Therefore, the strengthening recreational function of the area caused great changes in the structure of the landscape (*Szilassi P. 1999*).

- The third reason of the decrease and redistribution of vineyards is the disintegration of the local co-operatives and the privatisation of their lands. The new owners could not continue the cultivation of these lands because of the deficiency of founds or because it is not profitable any more.

The territory of forests changed in a reverse way (*Fig. 3*)

- On the upper parts of the hillslopes the forest limit had moved down to lower altitudes. The re-established forests are mostly locust stands, because on the edges of the basalt plateau the former vineyard owners planted locust.
- Other characteristic areas of the expanding forests are those former dirt roads, which were running downslope. They drain the running water and as a result they become erosional gullies very quickly, therefore, they are not in use anymore. On the airphotos one can nitice that along these gullies the forest belts and groves expand downslope.
- In the third case the expansion of trees started from the dispersely spotted groves on the middle slopes of the Fekete Hill. The number and area of these groves grew continuously between 1958 and 1993.

The expansion of the forests is in correlation with the retreat and suppression of vineyards and with the growing size of uncultivated lands.

Summary

Comparing the changes in land use structure during the last 30 years we can state that the area of vineyards was decreasing considerably (*Fig.4*).

Simultaneously, on the higher parts the reestablishment of the forests can be studied, and along the gullies the stands are largely expanding as well.

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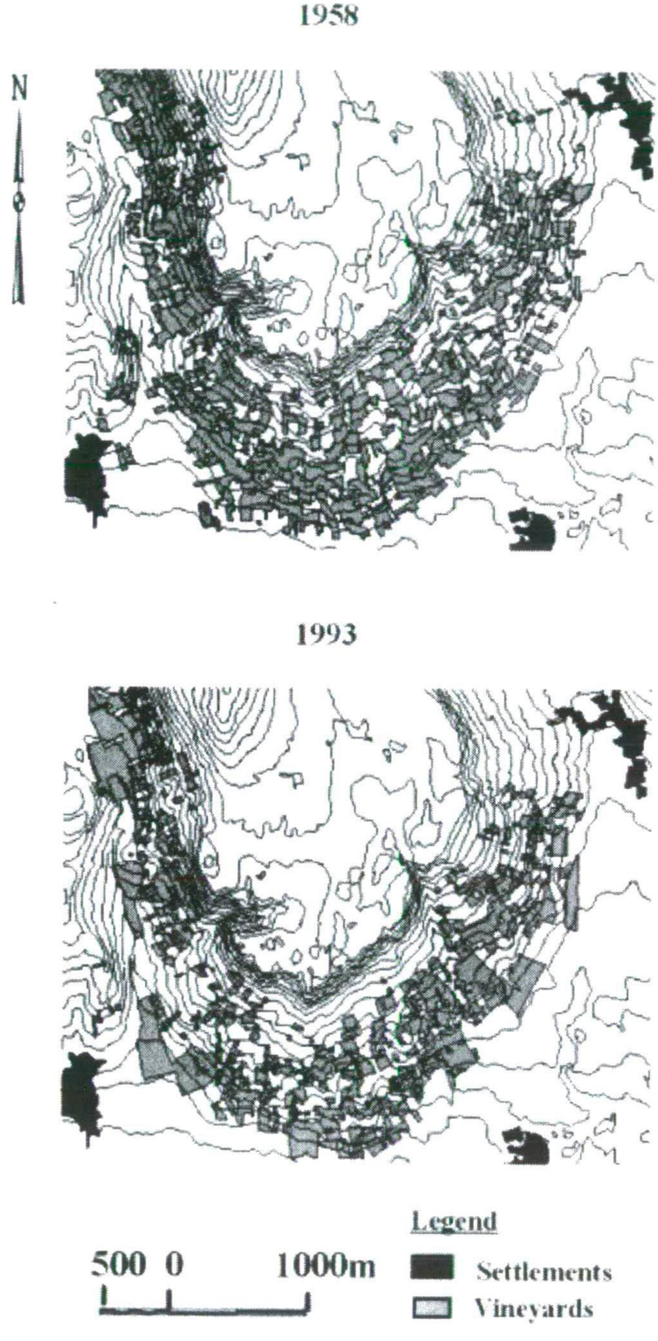


Figure 2 Territory of vineyards in1958 and 1993 on the Fekete Hill

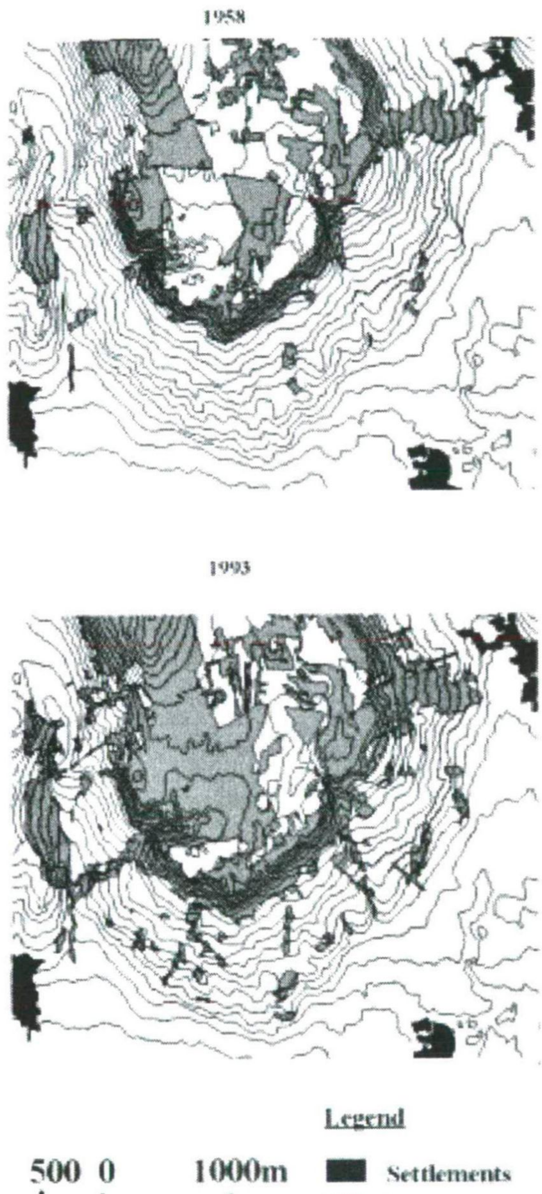
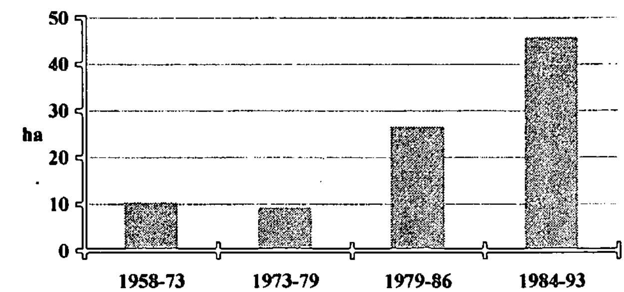


Figure 3 Territory of forests in1958 and 1993 on the Fekete Hill

A,



B,

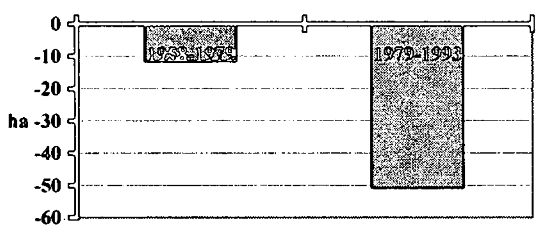


Figure 4 Changes in the territory of A, forests and B, vineyards between 1958 and 1993 on the Fekete Hill

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THE INDICATORS OF HEAVY METAL LOAD AFFECTING PEOPLE IN URBAN ENVIRONMENT: THE SPATIAL CHANGE OF THE HEAVY METAL CONTENT OF GREEN AREA SOILS AND DEPOSITED AEROSOLS IN SZEGED

Farsang, Andrea

Introduction

The living conditions, the feeling of comfort, the health risk of urban citizens can be characterised by several factors. Regarding these, the heavy metal load on the human body is of stressed importance, since, it is not its acute but rather the permanent, continuous low-grade-load that makes it dangerous. Usually this permanent load causes organic diseases and cancer only after long years.

The heavy metal load can affect the human body in five ways (*Fig. 1*): through nutrition, ingestion, direct contact, drinking water, and inhalation. In case of the first four ways of exposure, soil acts either as a direct or indirect factor. While, regarding the examination of inhalation, the spatial distribution of the heavy metal content of deposited aerosols must be investigated.

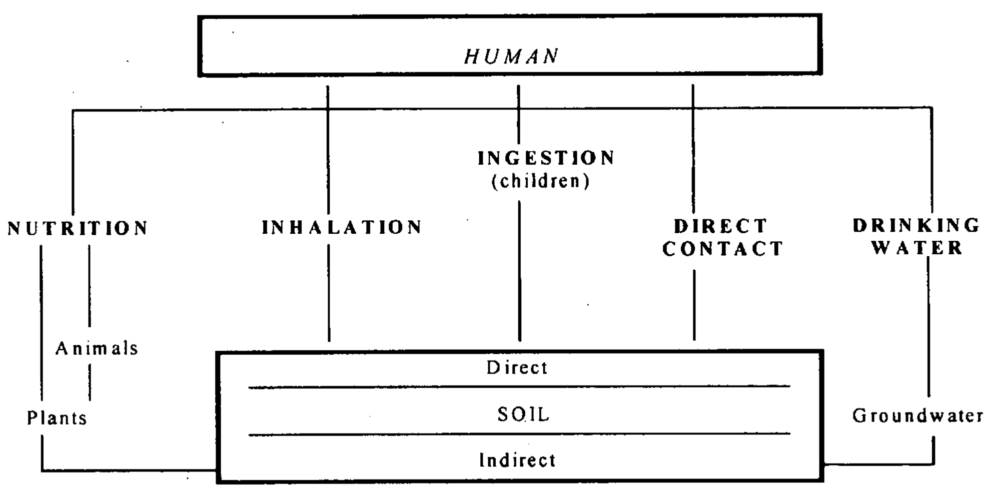

Figure 1 Heavy metal load, ways of exposure (*Ruck, 1990*)

The soils of the urban ecosystem can be classified into three groups (*Blume et al.*):

- natural soils that were built over
- natural, autochtonous soils that have suffered significant alteration
- artificial depositions containing both natural and technogenous (building rubble) materials

The soil classification system of the FAO puts these soils in a distinct soil group: Anthrosol (*Stefanovits et al. 1999*), containing anthropogenic soils that were formed or significantly transformed (removal of the upper level, deposition of other materials, etc.) by human activity. Concerning these soils the original soil-forming factors and the soil horizons can not be identified.

Threshold limit values on soils of different use (e.g. playgrounds, or gardens) refer to the possibility of acute or chronic damage of human health if thresholds are exceeded. However, the currently used threshold systems, like the Dutch list, the Berlin list, or the Eikman-Kloke type limit values can not be reasoned properly from a toxicological point of view (*Kádár 1998*), because the toxicological exposure, that depends on the use and the characteristics of the soil (physical soil type, pH, clay mineral content and quality, organic material content), can occur at lower and higher degrees of pollution as well.

In many cases, the examination of the soils of the urban ecosystem is equal with the analysis of the pollution of soils along roads of heavy traffic. Based on the results of such analyses, it can be ascertained that the heavy metal pollution of traffic origin is the highest to a distance of 50-100 m from roads, to a depth of 20-25 cm (*Árkosi, Buna 1990*). Nevertheless, the soils of these linear areas, due to the way of their use, do not have a major role in endangering the health of citizens. The situation is different in case of the soils of parks, playgrounds and urban green spaces. It is true that these soils contain 1.5-4 times less pollution in the upper horizon than those collected beside roads, but if we consider the possible ways of exposure, then the chance of affecting people is much greater in their case: inhalation of aerosols transported by wind, direct touch of the soils of playgrounds and sand boxes, children taking earth in their hands and mouth, cultivation of gardens within the urban area, eating of plants grown there etc. Based on experiments that were carried out on playgrounds (*Ruck 1990*), children around the age of two 0.4-1.5 times touch their mouths with their earthy hands in every minute. This kind of ingestion is called as the "pica" phenomenon. The 50-60 % of children between 14-24 months takes up soil orally. During another experiment the dirt was removed and collected from children's hand, and the daily amount of soil getting into their body was estimated based on these samples. The result was 100 mg/day. Such, so called ingestional exposure of children is characteristic between the ages of 1-6.

The analysis of the heavy metal content of soils is important from more point of views at the same time: it is one of the factors of soil pollution, and through inhalation it represents a significant proportion of the heavy metal load getting into the human body. During respiration the inhaled dust particles and aerosols, depending on their size, accumulate at different organs of the body. Pollutants larger than 5 μm first accumulate in the upper respiratory organs, then get to the stomach. Smaller ones can travel down even to the bronchi, and can cause various lung diseases.

Consequently, the air and environment pollution of a city is also resembled in the chemical composition of its soils and aerosols (*Kovács, Nyári 1984*). Data referring to these, provide information on the degree and spatial variation of potential danger on citizens.

Methods

The analysed 44 soil samples were collected in parks and playgrounds, if it was possible close to sand boxes (*Fig. 2*). Samples were taken from the upper 5-10 cm of the soil profile. After adequate preparations pH (H_2O), physical type following the Arany method, and organic material content (H_2SO_4 with the presence of 0.33 M $K_2Cr_2O_7$) were determined. The heavy metal content of soils was extracted in two ways. The "total" content was extracted with nitrohydrochloric acid, the environmentally mobile content with the method of Lakanen-Erviö (0.02 M EDTA solution of pH 7, set with ammonium acetate). The concentration of seven metals: Cd, Co, Cr, Cu, Ni, Zn, Pb were determined with atomic adsorption spectrophotometer, Perkin-Elmer 3110.

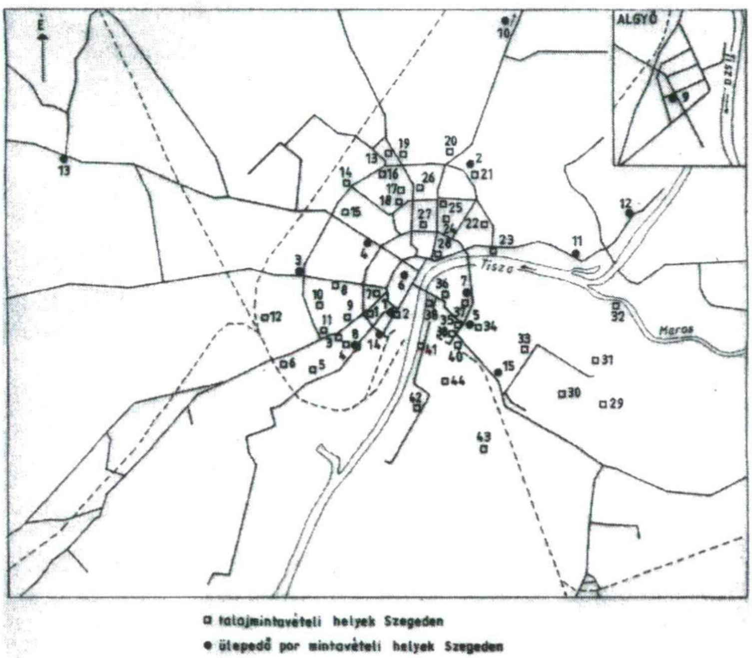

Figure 2 Sampling sites (*see also Table 3*)

The samples of deposited aerosols were collected in co-operation with the Csongrád County Institution of the ÁNTSZ (Public Health and Medical Officer's Service) at 15 sites of the city (*Fig. 2*) once in a month during the first half of year 2000, by following the MSZ 21454/1-1983 standard. Beside measuring the amount of deposited aerosols (g/m^2/30 days), Cd, Pb and Cu concentrations were also determined. The extraction was carried out with nitrohydrochloric acid (MSZ 21454/5-1988, MSZ 21454/11-1987), atomic adsorption spectrophotometer, Perkin-Elmer 3110.

The heavy metal content of Szeged green area soils

The pH of soils at the green areas of Szeged is practically uniform, and varies between 7 and 7.9. Their organic material content is high, in average 6.5 %. Considering their physical type, determined following the Arany method, the samples can be classified to the silt or clayey silt category. Since the mobility of heavy metals in soils is influenced mainly by the factors above, their analysis is of great importance when examining the ways of exposure (uptake by plants -> food chain, ground water -> irrigation -> plant -> food chain etc.). Nevertheless, because in case of the examined samples the pH exceeds 7, the organic material content is high and the physical type is silt or clayey silt, it can be claimed that these soils have a high toxic element adsorption ability, i.e. environmental buffer capacity concerning all the seven analysed metals (*Stefanovits et al. 1999*).

Regarding the examined heavy metals the pollution of soils is diverse (*Table 1*). In case of samples extracted with nitrohydrochloric acid, the concentration of Pb, Zn, Cr and Ni only in 2-3 occasions, while that of Cu in all cases exceeded the "allowable maximum amount", determined by the technological directives of the agricultural, provisional sector. The measured concentrations in the soils of Szeged can be compared to other referential data as well. For determining the degree of pollution, the results of analyses performed on soils of a city of similar size can serve as a good base: in Rostock Kahle et al. (*1999*) examined the soils of playgrounds with the same methods of sampling and extraction. Regarding all the examined metals, with the exception of Cr, their results were lower than the Szeged values. By comparing the measured values with the values of soils free from direct anthropogenic influence, it can be seen that the load on the green area soils of Szeged, i.e. the "background pollution" of the city is very significant. When focusing on the different sampling points, it is striking that in case of each metals the results of the samples collected at the playground beside the Szőregi Road, and at the ramp of the Downtown Bridge are higher than the limit values for urban soils. The above sampling points are located near busy junctions, where there is not any natural or artificial formations (bushes, trees or buildings) that would filter or shield the pollution of traffic. The sampling point on the floodplain of the River Tisza also refers to a high load. In several countries (e.g. Germany) – as opposed to Hungarian practise – different threshold limit values are established according to the different ways of land-use. The German limit values (*Table 1*) that refer to playgrounds were exceeded in several occasions by the results of the soils collected on the playgrounds of Szeged. The stepping over of the C value (toxic value: the object of protection (plant, animal, human) is harmed, intervention is needed) of this threshold system is not rare either (e.g. in case of Cd and Cu at the above mentioned sites). These data stress the increased background pollution in certain parts of the city!

	Cd	Co	Cr	Cu	Ni	Pb	Zn
Mean heavy metal content of urban soils (0-10 cm)[1]	0,48	-	20	16,6	-	37,3	66
Mean heavy metal content of soils free from anthropogenic load. [2]	0,1 - 0,5	-	5 -100	2 - 40	5 -50	2 - 60	10 – 80
Suggested thresholds on the basis of the way of soil-use – playgrounds [3]	**2**	-	**50**	**50**	**40**	**200**	**300**
Mean heavy metal content of Szeged green area soils	**1,77**	**46,79**	**17,47**	**270,39**	**30,16**	**47,04**	**109,82**
Heavy metal content of Szeged green area soils. Minimum value	0.20	15.25	5.44	198.89	9.19	11.05	11.77
Heavy metal content of Szeged green area soils. Maximum value	13.29	69.85	73.46	509.04	58.96	332.81	650.64
Mean heavy metal content of soils of playgrounds in Rostock [4]	0.17	-	17.9	6.1	5.1	15.0	28.4
Allowable maximum value in soils (T=15-25)[5]	2	50	100	100	50	100	250

Table 1 Heavy metal pollution of the soils of Szeged ("total" content, given in ppm)
1. Fiedler, Rösler 1993, 2. Brümmer et al. 1991, 3. Kloke 1980, 4. Kahle et al. 1999 5. Technological directives of the agricultural and provisional sector (January 1991)

In case of the mobile element content, the problem of exceeding thresholds is more obvious. Therefore, the results were compared to suggested (*Kádár 1998*), temporary threshold limit values (*Table 2*). According to this, on the whole territory of the city the Co and Ni concentrations remain under the allowed value, while the other elements, not rarely by several times, step over the limits. At the above mentioned sampling sites the Cu and Pb concentrations exceed the threshold by 3 and 5 times, respectively.

	Cd	Co	Cr	Cu	Ni	Pb	Zn
Mobile heavy metal content of Szeged green area soils (mean) (ppm)	0.205	3.913	**3.253**	**38.02**	5.467	**24.786**	14.486
Mobile heavy metal content of Szeged green area soils (minimum) (ppm)	< 0.01	1.19	1.08	13.03	2.77	6.55	1.59
Mobile heavy metal content of Szeged green area soils (maximum) (ppm)	2.69	5.29	**7.39**	**166.42**	8.79	**193.9**	**111.95**
Suggested, temporary threshold for the mobile element content (ppm) of soils (NH4 acetate + soluble EDTA) (B value)	-	10	3	40	20	25	20

Table 2 Environmentally mobile heavy metal content (ppm) of Szeged green area soils compared to the suggested, temporary threshold limit value (B value: the concentration above which the soil can be declared polluted), 1. Kádár, 1998.

The heavy metal content of deposited aerosols on the territory of Szeged

The heavy metals emitted to the air attach to the floating particles, aerosols (<1μm) of the atmosphere, and travel with these in the air. After a certain time they deposit onto the surface of the soil, plants and water. The travelled distance, and the time of atmospheric presence depends on the size of the aerosol and the meteorological conditions. Larger particles deposit quickly close to the source, while those, smaller than 10 µm leave the air very slowly, remain in the atmosphere for 7-30 days, and may travel several thousand km. When examining the urban environment, several other factors must be considered, too. The meteorological conditions that determine the principles of deposition (direction of wind, precipitation) are modified by numerous parameters: e.g. the built over ratio, vegetal coverage, high buildings modifying the direction of air currents, microclimate; the effect of which may result in great differences even in relatively small distances, too. Besides, regarding the different pollutants, the great variety of possible sources (transportation, industry, combustion of fossil energy sources etc.) makes the situation even more complicated. When examining the temporal course of the amount of deposited aerosols, we experienced in the winter months higher, while in the spring months lower values during year 2000 (*Table 3*). Values that exceeded the threshold limit values (depending on the degree of protection, 12-16 g/m^2/30 days) occurred only in March at certain parts of the city.

Number and location of station	January	February	March	April	May	June
1. Boldogasszony sgt.	2,5	2,5	11,5	7,9	6,9	8,2
2. Tarjáni óvoda	1,7	1,4	11,6	3,9	5,9	5,7
3. Vasöntöde	3,2	2,8	3,3	6,4	8,6	2,3
4. Kórház (Kossuth L. u)	1,9	1,7	1,5	6,6	11	2
14. Bécsi krt.	2,7	2,2	5,2	5,8	3,9	8,5
5. ÁNTSZ	1,9	1,6	3	4,7	6,4	3,8
9. Algyő, gyógyszertár	1,9	2	13,6	5,4	6,7	3,8
10. Algyő, olajos központ	1,5	1,7	6,9	5,4	7,2	3,4
11. Tápé, Budai N. A. u.	0,9	1,5	10,7	4,8	10,9	4,9
13. Kiskundorozsma	4,3	2,4	4,1	10,9	5,9	3,8
7. ÁVI, Újszeged	5,8	0,9	8,1	7,9	5	5,2
15. Ifjúgárda	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6. Széchenyi tér	4,2	1,5	4	8,3	n.a.	n.a.
8. Mátyás tér	n.a.	n.a.	2,3	3,9	7,1	3,6
12. Tápé, Templom	14,4	2	5	4,6	5	5,9

Table 3 Temporal change of the amount of deposited aerosols in Szeged, Jan.-Jun. 2000 (g/m^2/30 days). Air quality threshold limit value: 12 g/m2/30 days (MSZ 21854-1990)

In case of aerosol samples the concentrations of three heavy metals: Cd, Cu, Pb were determined. Compared to the 1990 standard about the requirements of the environmental air clearness, the Cd content of the deposited aerosols exceeded the 180 µm/m^2/30 days threshold value only once. In case of Pb – similarly to values in soils – the concentration in aerosols did not even reach the limits (*Table 4*). Regarding Cu, there is currently no threshold limit value (*Table 5*). However, if we count with an average 6000 µg/m^2/30 days Cu load in Szeged, then it results in a 0.48 ppm annual increase in the upper 10 cm of soils. These values – if we consider the already high concentrations in the soils of the city – can be regarded high, though, for finding the sources, further analyses would be necessary. It is characteristic of both the temporal course of Cu and Pb that during the winter months the concentrations in deposited aerosols are higher (*Fig. 3*).

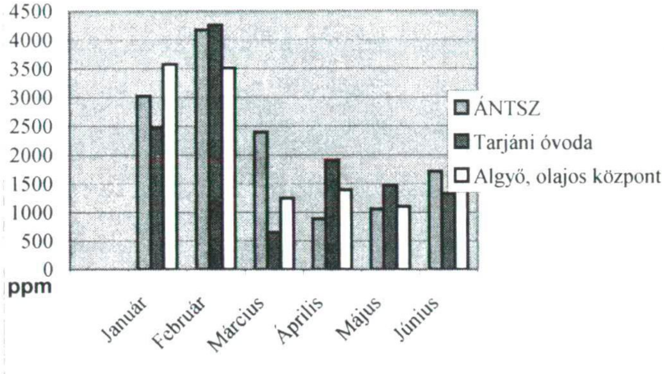

Figure 3 Temporal change of the Cu content of deposited aerosols in Szeged at three measuring points during the first half of year 2000 (*see also Table 3*)

Number and location of the station	January	February	March	April	May	June
3. Vasöntöde	476,224	361,536	256,212	991,616	3037,9	406,686
4. Kórház (Kossuth L. sgt.)	339,758	366,928	111,945	451,044	770,44	400,92
14. Bécsi krt.	420,633	383,372	825,968	213,092	230,95	167,365
5. ÁNTSZ	348,517	202,464	186,3	118,44	176	291,688
9. Algyő, gyógyszertár	1413,239	269,58	1538,70	294,138	578,41	295,716
10. Algyő, olajos központ	429,525	273,343	-	240,624	211,82	240,21
11. Tápé, Budai N. A. u.	167,967	374,715	2759,74	181,872	-	329,672
13. Kiskundorozsma	-	302,016	258,464	706,865	448,87	473,29
7. ÁVI, Újszeged	-	222,219	778,977	573,935	298,2	374,036
15. Ifjúgárda	-	-	-	-	-	-
6. Széchenyi tér	637,392	444,315	915,2	201,192	-	-
8. Mátyás tér	-	-	138,368	-	390,5	984,96
12. Tápé, Templom	1057,392	143,58	338,1	228,574	232,5	902,641

Table 4 Temporal change of the Pb content of deposited aerosols in Szeged, Jan.-Jun. 2000 ($\mu g/m^2/30$ days). Air quality threshold limit value: 12000 μg/m2/30 days (MSZ 21854-1990)

Number and location of the station	January	February	March	April	May	June
1. Boldogasszony sgt.	5669,75	8409,6	4754,79	8535,634	7847,232	7872,328
2. Tarjáni óvoda	4202,111	5961,284	7486,176	7451,769	8640,491	7581,798
3. Vasöntöde	4546,784	4573,52	9098,76	9645,184	10051,25	6958,742
4. Kórház (Kossuth L.)	7375,078	7473,251	6680,595	8574,852	10056,75	6623,24
14. Bécsikrt.	5063,958	6145,832	4555,356	6574,822	6600,009	3527,33
5. ÁNTSZ	5746,626	6674,464	7187,19	4200,719	6788,544	6512,972
9. Algyő, gyógyszertár	3834,447	4120,54	3941,008	7925,958	8560,791	7028,822
10. Algyő, olajos központ	5369,01	5964,11	8645,562	7528,95	7988,688	6167,838
11. Tápé, Budai N. A.	6741,171	5750,94	7836,038	4858,992	-	6882,54
13. Kiskundorozsma	-	4019,136	6725,599	17631,84	9283,532	7235,922
7. ÁVI, Újszeged	-	6233,337	64854,68	9346,095	8219,95	8814,884
15. Ifjúgárda	-	-	-	-	-	-
6. Széchenyi tér	5471,844	3420,45	8230,4	15701,69	-	-
8. Mátyás tér	-	-	6289,051	-	8794,841	6094,404
12. Tápé, Templom	7034,832	7441,58	7221,2	7049,914	8155,75	7948,244

Table 5 Temporal change of the Cu content of deposited aerosols in Szeged, Jan.-Jun. 2000 ($\mu g/m^2/30$ days)

In order to reveal the spatial distribution of the concentrations, detailed microclimatic investigations are needed.

Conclusion

The quantitative and qualitative examination of deposited aerosols is an important additive in the proper judgement of the health of our environment, and the surveying of the background load on soils and citizens. This was the aim when we analysed the heavy metal content of the 44 soil samples collected from the green areas, parks, playgrounds of Szeged, and that of the aerosol samples gained at 15 measuring stations of the city. Our results, compared to the values measured in other cities, and the referring threshold limit values, imply significant background pollution. Therefore, we suggest that the decrease of anthropogenic health risk would need a greater attention. Possible methods of treating the problem can be the establishment of green stripes beside junctions of heavy traffic, the ensuring of continuous vegetal coverage (grass) in order to avoid the formation of dust and inhalative pollutants.

The examinations on soils and deposited aerosols were supported by the F 024166 Youth OTKA. Special thanks to the Csongrád County ÁNTSZ for helping during the sampling of aerosols.

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SURFACE OZONE IN HUNGARY

Divéky, Erika

In Hungary if somebody mentions the word ozone, naturally at first, most people think about the nowadays fashionable problem of the ozone hole, then to the expression: 'descent, good, ozone-rich air'. Although, from the 1970s several Hungarian authors mentioned that ozone is not a totally positive notion, somehow, almost exclusively the bright side of ozone have remained in the public thinking. On the internet if we search on the word ozone, then most of the displayed Hungarian homepages are the sites of hotels or pensions, and advertisements similar to the following: "Ozone Pension – the pension of ozone-rich air, silence, comfort and peace"/1998/[1] are not rare either.

Is it a kind of laziness, self-protection or something else that we care more about problems that exceed our competence than those we could affect? Or maybe the media does not emphasise the problem properly, or it would bring uncomfortable changes, and who knows how many other alternative reasons are there to justify ignorance?

An informing programme that aims at to change public attitude could result positive changes, but unfortunately no programs of this kind have been started yet. TV and radio rarely speaks about the problem of surface ozone or the summer smog and if they do so, it is often broadcasted in environmental programmes which do not reach to everybody. "Only one, out of date device monitors the dangerous gas" – wrote the journalist of the newspaper Blikk on 15th of June 1998. Although this statement is not true, the situation is far from rosy.

After a long lasting inquiry and telephoning we found four organisations that perform ozone-measurements beside the monitoring of other air pollutants. There are 5 stations in Budapest and other 25 in the rest of the country that currently measure ozone concentration, 4 others measured it previously for a short term, and several stations plan to measure ozone in the near future (*Fig. 1*).

The four organisations are: Hungarian Meteorological Service [Országos Meteorológiai Szolgálat] (OMSZ), Public Health and Medical Officer's Service [Állami Népegészségügyi és Tisztiorvosi Szolgálat] (ÁNTSZ), Environmental Inspectorate [Környezetvédelmi Felügyelőség] (KÖFE), and the former Northeast Hungarian - Japanese monitoring system's (Djayka Programme) only remained station, that is operated by the local ÁNTSZ. Unfortunately, even the authorities, organisations that deal with the problem do not have an overall, up-to-date view of the situation, and they do not know about each other's similar programmes.

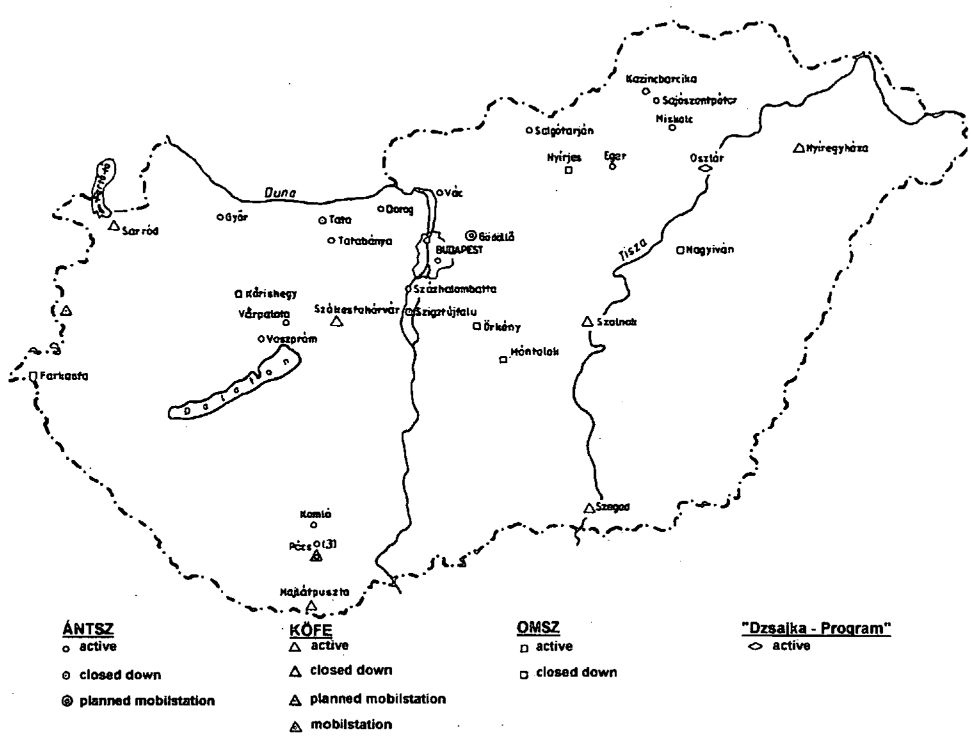

Figure 1 Stations in Hungary

In principle, data are free to get for scientific purposes, but in practise this does not work everywhere. At some stations it is not clear either, who has the right to deliver and to receive these information. A year ago we asked 36 stations, first on phone then in letter, to provide us hourly data from 1997 for a comparing research of mine. Up till now 18 stations have sent the asked information. We chose the 1997 data, because this was the latest available data series that was already processed by computers, and in many places, e.g. in Szeged, the monitoring was launched in that year. There were institutions that asked for money, others wanted to deliver half-year mean results. In the end some stations sent annual means saved on disc (at best) or in the form of a printed diagram (at worst). However, there were positive examples, too: Eger, Szolnok and the OMSZ sent the required data immediately in e-mail. Finally, we have to stress that as an outstanding example – in Hungary – the latest hourly results and the previous week's data of Eger are published on the Internet.

In Hungary the first measurements were carried out with the Schönbein - method in the middle of the 19^{th} century. As a result of this, we have daily data from Sopron and Szeged, where two measures were performed a day from 1874 to 1881 and from 1855 to 1856, respectively.[2] After the trials at the end of the 19^{th} and the beginning of the 20^{th} century, surface ozone measurements were started again only at the end of the 1980s. The first station /a background station/ was established near Kecskemét, at K-puszta (at Méntelek) in 1990.

Most of the instruments (22 pieces) in Hungary were installed in the framework of a PHARE programme in 1992 (now 17 instruments are operating).[3] None of these were installed in Szeged, that is called the "city of sunshine" (not insignificant regarding ozone), and that is the 5th on the ranking list of the 23 most polluted Hungarian cities.[4] In Szeged the first and till now the only instrument was installed near an avenue with heavy traffic in 1997 with the financial aid of some great local companies. Regarding ozone measurements the place of installation is not really ideal, but in the Hungarian practise this failure is not unusual. With the exception of six background stations, operated by the OMSZ and the KÖFE, measurements are mainly carried out by traffic and city background stations (previous ones are more characteristic). The reason for this is that these instruments also measure the concentrations of other pollutants that are present in the greatest amount where traffic is heavy. The place of measurements is determining, since, where the concentration of certain primal air pollutants (CO, NO_x, VOC) is high, there the ozone breaks down quicker, and lower values are measured than e.g. in a low traffic area of the city /park, playground/.

The financial situation of organisations dealing with ozone measurement is very different. The ÁNTSZ is subsidised by the Ministry of Health. The ÁNTSZ claims that one third of the necessary money is covered by the subsidy, and the remaining amount has to be raised by themselves. Regarding ozone measurements the KÖFE and the OMSZ belongs to the Ministry of Environment, but the structure of the budget of the KÖFE is similar to that of ÁNTSZ.

The price of a measuring instrument is 2-3 millions HUF, and the maintenance is also expensive. In case of some stations, even operation costs are a problematic issue. This is how it could happen that a station's whole 1995 database is invalid, since in that year, partly because of financial reasons the instrument was not calibrated. Failures the reparation of which may take weeks are regular. Naturally, the data of these failure periods are missing. Among others, heat was emphasised as a reason for faults, since the instruments, placed in containers, cannot stand extreme heat, and they stop. This means that the devices go wrong exactly when they would be the most necessary, i.e. on the hot days, occurring regularly, between May and September.

"Health and environmental institutions – due to reduced financial circumstances – in a limited degree but continuously carry out the evaluation of air quality and its effect on the health of the population".[5]

In Hungary, the directive on the acceptable threshold limit values of ozone concentration is recorded in the MSZ 21456-26:1994 standard. It gives a 110 $\mu g/m^3$ hourly and a 100 $\mu g/m^3$ daily mean value as a limit for ozone concentration.[6]

In Budapest a smog raid is to declare if at least at two stations of the monitoring system the imission values reach or exceed the threshold value, and if no significant change can be expected in the weather situation. Consequently, the declaration of a smog raid is partially based on the forecast of the OMSZ. The problem is that two out of the three standard instruments ('monitoring system') are at traffic stations and it is not very probable that the given threshold value will be reached there. According to smog raid regulations, the raid must be declared by the competents of the Council of Budapest on the basis of the suggestion of the ÁNTSZ and the OMSZ. Restrictions on traffic can be declared, or industrial emitters can be requested to cut back their emission.[7] Budapest's action plan can be found in the Fővárosi Önkormányzat Hatályos Rendeletei (1st December 1994, 31st August 1998) and in the Fővárosi Közlöny (25th March 1998).

As a comparison, in *Table I* the threshold values of Budapest can be seen together with the corresponding German whole-country values. Differences can be noticed not only in the values but in the referential temperature, as well. While according to the EU standards, the members, so as Germany, apply 20 °C and 101,3 Pa for reference, in Budapest the results are referred to 25 °C and 101,3 Pa. [8] (Obviously, the higher the referential temperature is, the lower ozone values we get).

	preparedness	raid I.	raid II.
Budapest	200 μg/m³	200 μg/m³	200 μg/m³
Germany	200 μg/m³	200 μg/m³	200 μg/m³

Table 1 Limit values for ozone in case declaring smog raid

According to the laws, every local government can decide whether it needs or not an action plan for smog raid situations, thus, the above mentioned plan refers only to the capital. Beside Budapest, only Pécs has compiled a similar plan yet. However, the drawing up of local action plans is not effective – as it was proved in several researches –, since surface ozone is not a local problem. Exactly because of this, most of the western countries usually prepare a regional or countrywide action plan.

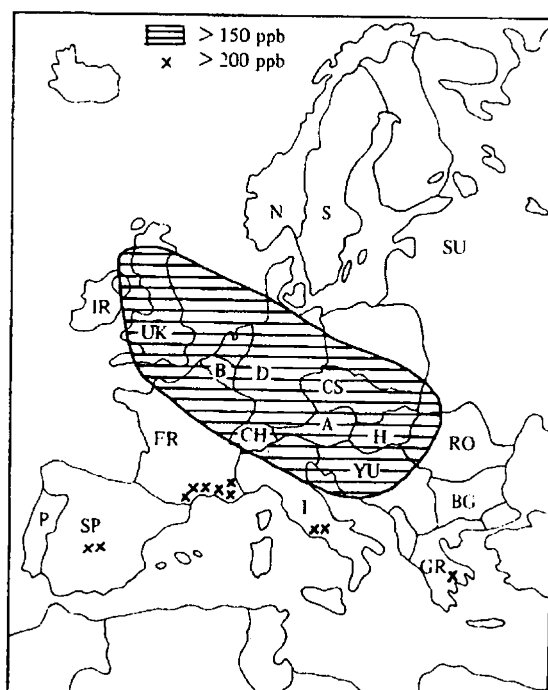

Figure 2 Phoxa Model

"No summer smog has occurred in Hungary yet" – claimed an ÁNTSZ employee. "That is how, unfortunately, there has not been any chance to test the suitability of the smog raid plan." The question then is: how is it possible that there has not been summer smog and smog raid in Hungary yet, if in other European countries (e.g. Germany, or the neighbouring Austria) this is a permanent problem in the summer. On the basis of certain models, we can also question the absence of summer smog in Hungary.

On *Fig. 2* those parts of Europe are coloured where according to the German - Dutch Phoxa Model (Photochemical Oxidants and Acid Deposition), the hourly mean ozone concentration can reach 150 ppb, i.e. 300 μg/m^3. In 1985 for mapping the real situation and to support previous models, in the framework of the so-called OXIDATE Project a measuring system of 25 stations was established in Western Europe. The results of this project have shown that due to the spatial distribution of emitters and the predominant climatic circumstances, the concentration of surface ozone has a distinct NW - SE gradient, therefore, ozone concentration significantly increases towards Hungary [9]. *Fig. 3* was compiled by the EMEP (Co-operative Programme for Monitoring and Evaluation of long Range Transmission of Air Pollutants in Europe), and it was published in the 1995 and 1998 report of the European Environmental Agency both. On the figure almost the whole territory of Hungary is coloured dark, which refers to those areas of Europe where the daily means in the summer can be expected to exceed 52 ppb.[10]

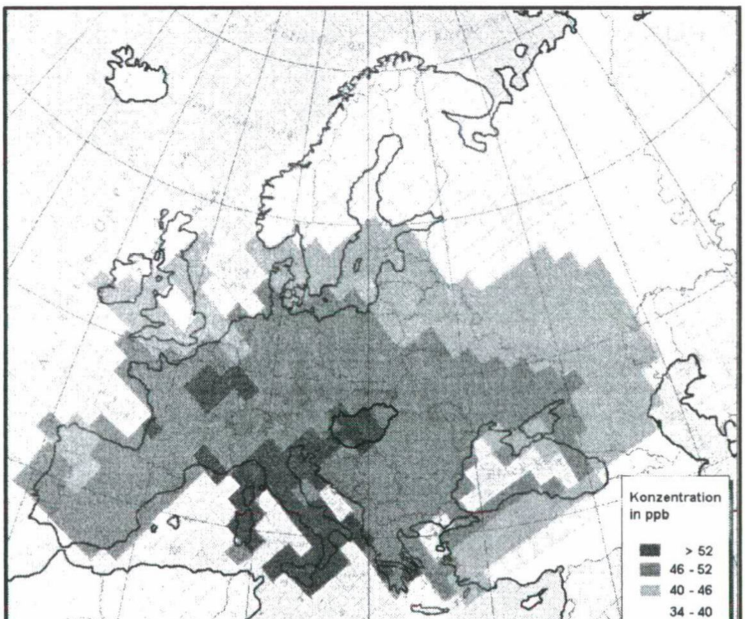

Figure 3 Five year mean of daily maximums in the summer, based on the EMEP-150-Raster /EMEP Model/

Based on the above two examples, the fact that the concentration of ozone in Europe increases from West to East, and according to the reports of the European Environmental Agency – their annual report announces the limit oversteps, and e.g. it reports on threshold value oversteps in Austria regarding stations close to the Hungarian border – in Hungary similarly high values should be found as in Austria and Germany. The following figure of the 1995 ozone-report of the European Environmental Office marks limit (180 μg/m^3) oversteps measured in background stations. In the ozone-report of the EU the results of the background stations are referred to a circle of a radius of 100 km around the measuring point. In case of Austrian stations that are a few km far from the Hungarian border, a series of daily means exceeded the threshold value. At most of the stations close to the border, the number of days with overstepping results ranges from 1 to 5 days, and 'only' one station was ranked to the 5 to 10 days category (*Fig. 4*).

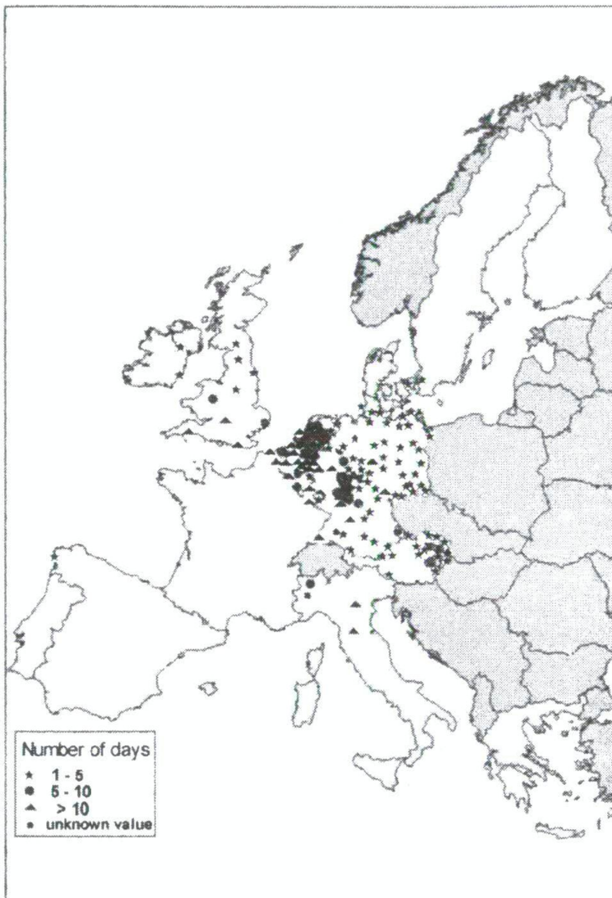

Figure 4 Number of days on which an hourly mean exceeded 180 μg/m^3, at background stations in 1995 [12]

Although, the increase of ozone concentration toward the border has been proved by all means, no increase has been detected eastward of the border. What can be the reason for this? Is there really a dividing line that terminates regularities?[11] Or maybe the instruments are operating between different circumstances, with different settings?

Beside the automatic calibration, devices must be checked in referential laboratories from time to time. Such referential laboratory works in Budapest at the Environmental Institution [Környezetvédelmi Intézet], but the service is not free, and as we have seen, the measuring organisations are in short of money. One of the answers for the question: where and how often are instruments calibrated, was the following: "the station has to decide: it pays for maintenance or for calibration, both tasks, because of financial reasons cannot be carried out everywhere".

In principle, the calibration of the Hungarian instruments and the devices of the OMSZ belongs to the Central European Central Laboratory in Prague. The Czech laboratory offered a co-operation for the Hungarian referential laboratory, but at the measuring organisations it is not known whether they accepted the offer or not.[13]

Hungarian researches concerning surface ozone have started in the middle of the 1980s. At the end of 1987 Hungary joined to the EUROTRAC (European Experiment on the Transport and Transformation of Environmentally Relevant Trace constituents on the Troposphere over Europe), a sub-programme of the EUREKA Project. In the framework of the EUROTRAC, in the TOR (Tropospheric Ozone Research) Programme we participated in a research that examined the changes of tropospheric ozone concentration over Europe with exact measurements and modelling. One of the stations of the network was placed near Kecskemét at K-puszta. This station is one of the most eastern stations in Central Europe.[9] The major issue of the Meteorological Scientific Days [Meteorológiai Tudományos Napok] held in Budapest in 1990 was also ozone. Consequently, the actual problem is not the lack of Hungarian researchers dealing with this issue, but rather the communication of the results toward the public. Most of the papers dealing with surface ozone in Hungary are published in scientific periodicals that do not get to average citizens. Besides, many of these periodicals are written in English recently which is useful if we consider that foreign scientists can get a view of the Hungarian situation, but on the other hand, those who live here and do not speak English – although this is the language of natural sciences – cannot always utilise these writings.

One can receive air pollution data in terms of only a few cities (supposedly with a week delay) in the TV's weather report, nevertheless; at most places results by no means get to the citizens.

What could be improved easily is the informing work of the media. Basically a general informing should be started about the effects, measurements, and researches in order to avoid desinforming, what is unfortunately quite regular regarding this issue. Even the latest instruments, the best measuring systems are unworthy, if there is no environmental commitment and feeling of concern.

The already mentioned Blikk article also quotes the president of the Environmental Committee of Budapest: all of the smog measuring instruments are out of date, some are always wrong, no spare components are available. The price of a new device is 20 million HUF. Environmentalists claim that 30 stations would be necessary in Budapest, the president says 14 -15 would be enough. This would require a 300 millions HUF investment from which 214 millions HUF was approved by the Council of Budapest. Although, the article deals only with ozone, the situation is naturally similar in case of the measurement of other pollutants, as well. According to the examples of other countries, in case of an accurate installation 5 -6 operating instruments would be enough in a city, like Budapest. However, the project mentioned above remains a plan, since it cannot be carried out because of financial reasons.

According to an article published in a leading Hungarian newspaper (Népszabadság) in 1997: "Today almost every child in Budapest knows what is surface ozone". We find this statement a bit strange. But let it be true, then it might be better to inform adults of this problem, too, and waiting not until children grow up.[14]

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INTRODUCION TO RESEARCH PROJECT ORGANIZING FOR CHARACTERIZATION AND MONITORING OF THE ENVIRONMENTAL EFFECT OF PETROLEUM INDUSTRIAL CONTAMINATION IN HUNGARY[1]

Mucsi, László – Varga, Szilvia – Miki Ferenczy

Introduction

There are currently over 20,000 registered contaminated sites in Hungary. The estimated cost of the remediation of these known sites is approximately 2 billion USD. The delineation of the contaminated areas and their associated sources is an extremely complex process due to the different types of contaminants and their associated persistence and migration, as well as the media in which the contamination is present (e.g. in soil, vegetation, and groundwater). These contaminants pose an immediate and long-term threat to the local population, flora, and fauna. This threat is increased by the movement of the contaminants through the soil, surface- and groundwater. In the agricultural regions, heavy metals can be absorbed by cultivated plants. These heavy metals are known to be extremely toxic to humanity and fauna who ingest the plants. Heavy metals are known to bioaccumulate in animals, thus the body burden of these often increases up the food chain. This poses a significant risk for humans.

The proposed research program seeks to clearly identify and locate the suspected and unknown contaminated areas and their corresponding sources. The investigation also will assess the extent of the contamination and it's associated effects on the flora and fauna. The project will utilize state-of-the-art techniques in remote sensing, material science, geostatistics, information management, and cartography.

Research area

The exploration of natural oil and gas began in the mid 1960's in the southern part of Hungary. The Algyő Oil and Gas Field belongs to the Hungarian Oil and Gas Company Ltd. (MOL) and is the largest oil and gas field in the country. The field is comprised of 24 km^2. This field provides a significant portion of the energy supply to Hungary. There are in excess of 1000 oil wells within this field. (*Fig 1-2.*)

During the intensive drilling operations, various additive materials containing high levels of heavy metals (Cr, Pb, etc.) were utilized. These contaminants were deposited in the area of the existing wells. In one so called „near-well soil disposal" area, varying amounts of contaminant material (ranging from 100 to 1000 m^3) were deposited. This method of disposal

[1] *The research programme is supported by the following organizations and fellowships:.a. OTKA no. T035121 (2001-04), b, OTKA Equipment fellowship no. M 36762, c, Ministry of Education contract no. 00018/2000 OMFB, d, Bolyai Fellowship 1998-2001. e, Szechenyi István Fellowship 2001-2003*

was used from mid 1960's to 1990 at such wells, which were deeper than 1800 m. To further complicate matters, the locations of the former disposal sites have been forgotten.

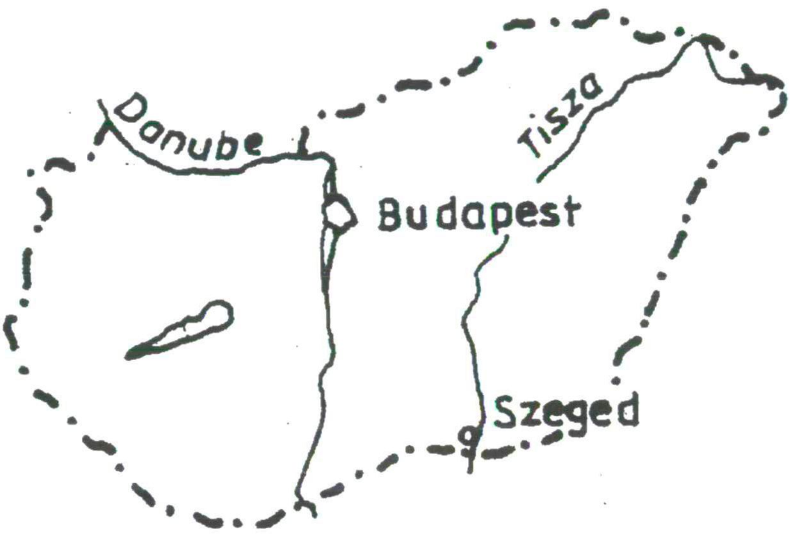

Figure 1 Map of Hungary

MOL is one of the leading integrated oil and gas companies in Central and Eastern Europe. MOL's primary activities include the exploration, production and refining of crude oil and natural gas, the transportation and storage of raw materials and related products, as well as the marketing of their own products.

Environmental protection is an integral part of MOL's business philosophy and practices. MOL's official policy with respect to the environment was quoted as: *"We wish to carry out our activities with the protection of the natural environment, keeping in view that our products and services should be benign to the environment."* In 1995-96 the environmental responsibilities of the Hungarian Oil and Gas Co. Ltd. were evaluated by independent auditing firms prior to the company's initial stock offering. According to the report, one of the most important tasks is remediation of the contaminated regions associated with the near-well disposals (ca. 20 million USD).

One of the most important conclusions of the report was that the environmental impacts of activities must be assessed, regularly evaluated, and monitored over time. The adherence to these recommendations will allow efficient operations while minimizing the impact on the environment.

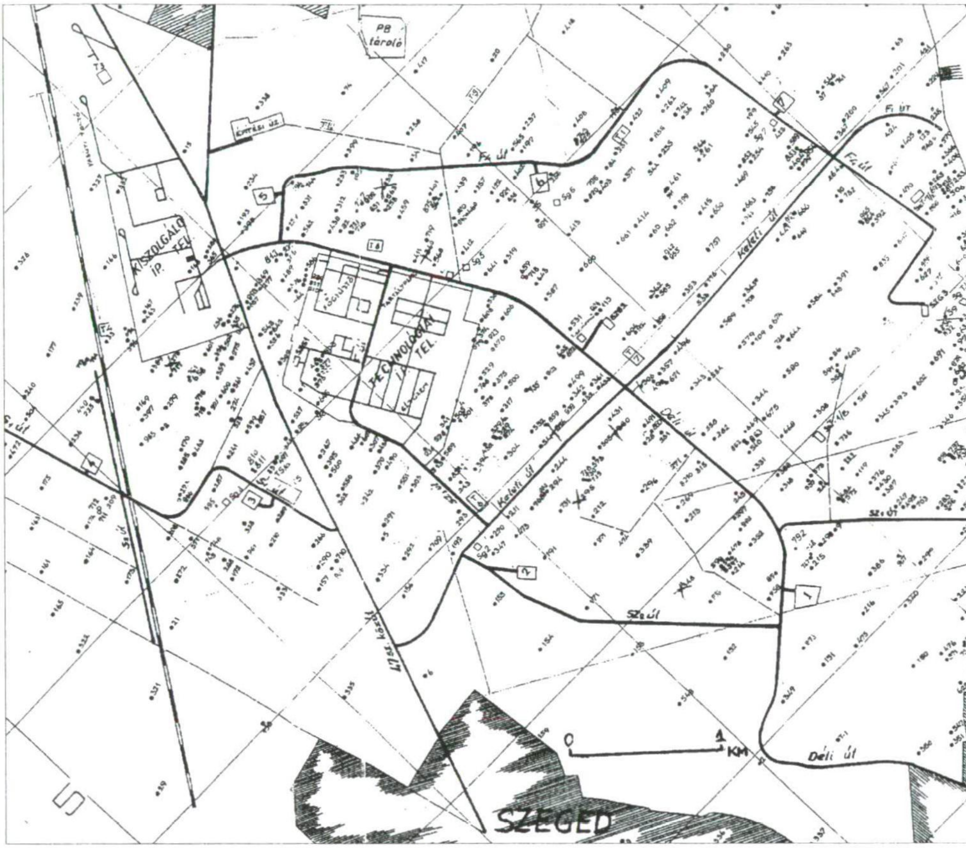

Figure 2 Map of Algyő Oil Field with the oil and gas wells depicted

The City of Szeged's Environmental Plan contains a section pertaining to the remediation of the contaminated regions associated with the near-well disposals. There is a formal agreement between the Hungarian Oil and Gas Company Ltd. and Hungarian Government regarding the location, characterization, and remediation of the disposal areas. The industrial waste disposals are primarily located in agricultural areas and according to previous analysis the heavy metal contents of cultivated plants are much higher than regulatory levels. Due to the geological and hydro-geological conditions of the region, the aquifers are particularly threatened by contamination. The hydro-geological conditions facilitate contaminant transport to the Tisza river (*Fig. 3-4.*).

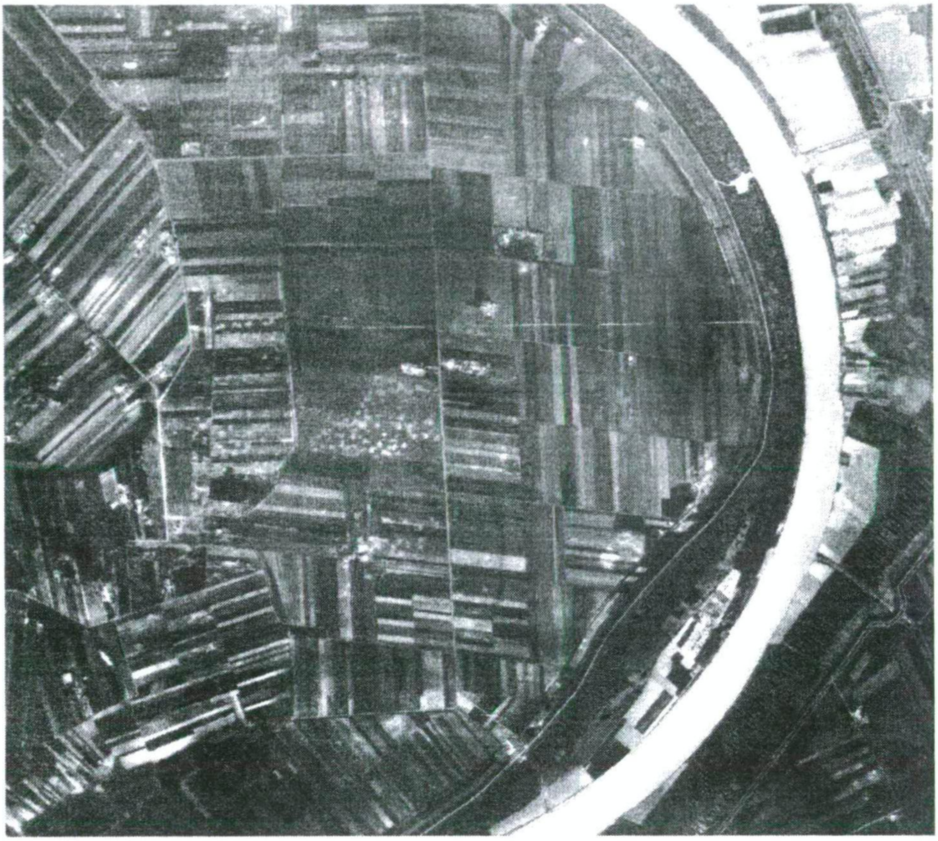

Figure 3 Cultivated area was on the current oil field in 1950 (BW aerial photography – Database of Ministry of Defense)

The goal of the research programme is to identify, locate, and map the positions of the near-well disposals, and to subsequently assess the effects of selected representative (4-5) contaminants by complex analytical methods (remote sensing, geo- and hydro-chemical analysis, GIS based environmental modelling, etc.). These analytical tools and modelling results will then be deployed as a continuous monitoring system covering the entire oil field.

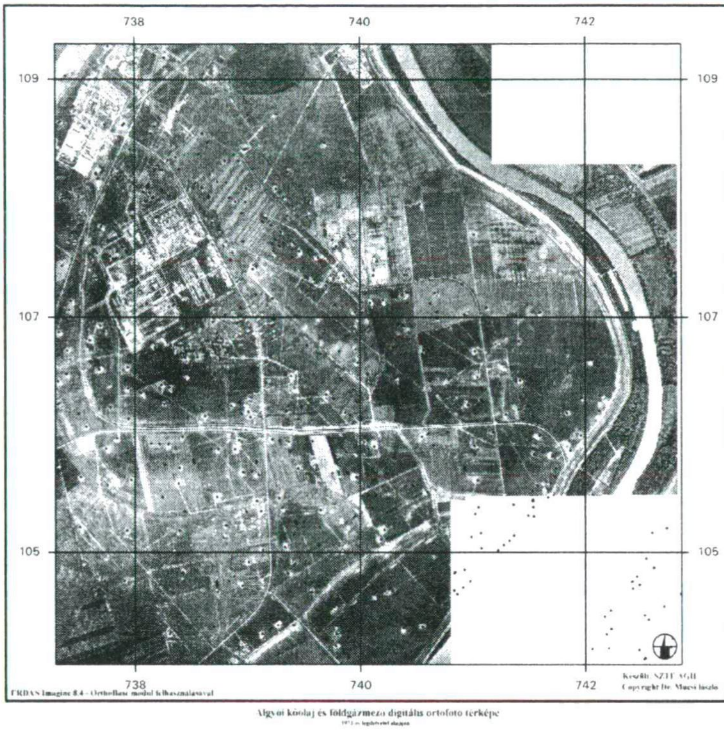

Figure 4 Aerial photography of part of oil- and gas field in Algyő. Ortophotography from BW airphotos (database of FÖMI) developed in the Applied Geoinformatics Laboratory, Univ. Of Szeged

Expected results

1. Contaminant map of study area

The use of aerial remote sensing methods coupled with field data acquisition will allow us to identify contaminated areas in a time- and cost-effective manner. Hyper spectral remote sensing instruments can provide detailed information about the complete spectral reflectance of objects on the earth. A key goal of this project is to determine how to best analyse these data to help researchers differentiate between contaminated and non-contaminated soils and vegetation. The hyperspectral field spectroradiometers and airborne imaging sensors deployed in this research will provide information on the nature and extent of the contamination. This will greatly facilitate and expedite the site characterization.

2. Groundwater and contaminant transport modelling

Depending on the level of funding, between 30 and 50 monitoring wells will be placed in and around the study area. Soil samples will be obtained based on a comprehensive sampling plan. The soil samples will be analyzed using both physical and chemical analytical methods. The testing will be conducted by the Department of Physical Geography. They will measure the contaminant concentration by atomic absorption photometric methods. A detailed soil and surface geological map will be developed based upon these data by the Hungarian Geological Survey.

The contaminant transport modelling will be performed using data from the continuous groundwater monitoring stations set up in the wells. An existing GPS with 1 cm geodetic accuracy will be using for all field data acquisition. The combination of groundwater levels and chemical sampling data will be fed into a contaminant transport model and output into ESRI's ARC/Info GIS software. This will provide information on the concentration and migration of contaminants (i.e. heavy metals) in the groundwater.

In the frame a scientific research programme supported by OTKA (Hungarian Scientific Research Fund) – no. 035121.- 15-20 groundwater monitoring wells can be extended. on Algyő oil field in 2001. The positions of the wells are determined by geologigal and geostatistical methods based on former database of groundwater network located on tankstations of MOL.

3. Remote sensing database

Spectral reflectance will be measured by using a field spectroradiometer (multi-channel – up to 150 channels, 1-2 nm wavelength) in natural field conditions. The data will be further analyzed in the laboratory for radiometric and geometric calibration. The results of these field data studies will be the basis for the analysis of hyperspectral image data provided by aerial imaging spectroradiometers. The changes in spectral reflectance of the vegetation and soil will be measured under different conditions to delineate and characterize the extent of contamination. The results of this process and the spectroradiogram libraries for different pollutants will be published on the Internet, so that other researchers may benefit from our work.

4. Thermal mapping for continuous monitoring

Thermal mapping will require additional equipment due to the fact that a different portion of the spectrum is being measured. The difference between the emittance of natural and contaminated / disturbed soils can be measured by thermal imaging radiometers. In addition to the contamination of the near-well disposals, the other significant source of contamination is the old pipeline system connecting the wells and stations. The pipeline contains various fluids (water, natural oil, etc.) which are under high pressure and temperature, therefore the thermal effect of the outflowing material can be measured prior to the pollutants reaching the surface and causing changes in the spectral characteristics of the soil and vegetation. In a sense, thermal mapping may provide an „early warning" system for the future monitoring of the field.

On the frame of a research programme supported by Ministry of Education (contract no. 00018/2000), an environmental monitoring system and decision making method will be developed based on thermal images and former aerial photographies. The Department of Physical Geography (coordinator László Mucsi associate professor), A.A. Stádium Kft. (repersented by Gábor Dabis engineer) and ERMI Bt. (represented by Mihály Dzsupin) are in the consortium. The 18 months long research program will be finished in 2002.

Figure 5 Aerial photography of underground pipelines on the oilfield. On the bottom right corner basement of an oil well can be seen.

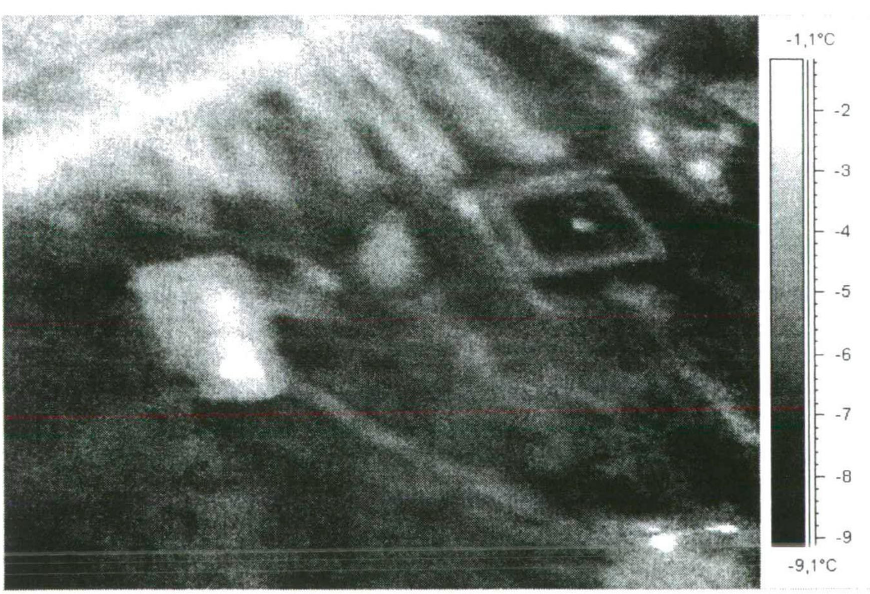

Figure 6 Thermal camera image of an oil- and a thermal water well acquired on February, 2000.

Science and Technology involved

Due to the complex nature of this project, it is essential to utilise interdisciplinary methods and state-of-the-art instruments for the research. The primary focus of the research project is the use of thermal and hyperspectral remote sensing to delineate surface contamination.

Satellite and airborne remote sensing technology has been used to effectively monitor the dynamic changes and disruptions in the environment for over 25 years. Synoptic viewing and short-cycled revisit capabilities of the current satellite sensors allow for effective monitoring and mapping of dynamic changes in the environment. More recently, the miniturization of these technologies has allowed the propagation of field based remote sensing technologies (i.e. portable spectroradiometers). The recent advent of advanced mapping technologies, i.e., Geographic Information Systems (GIS) and the Global Positioning System (GPS), has greatly facilitated the use of remotely sensed data for environmental monitoring. While remote sensing provides an expedited means of GIS data acquisition, GIS and GPS provide increased accuracy and utility of information which is extracted from the analysis of remotely sensed data. These technologies significantly enhance the accuracy and timelines of monitoring and managing the environment and associated natural resources.

Methodology

Remote sensing technologies measure the reflectance and/or emittance of energy from the earth's surfaces. Each material possesses a characteristic spectral signature based upon how much incident energy is absorbed, transmitted, reflected and emitted. In certain wavelengths, uncontaminated soil and vegetation possess distinctly different spectral signatures from their contaminated counterparts. Hyperspectral sensors split the spectrum into extremely narrow bandwidths thus providing detailed information on the nature and state of the surface in question. Data acquired at a high spatial resolution allows the discrimination of relatively small surface objects (i.e. individual plants). The analysis of hyperspectral data should be able to clearly identify those surfaces (soils, vegetation, etc.) which are contaminated with select contaminants (i.e. petroleum, heavy metals, etc.).

Based upon this methodology, the analyses should clearly distinguish the contaminated portions of our test sites. This project will serve as a pilot study to provide a proving ground for this methodology. Based upon the project results, this methodology can be applied to much larger regions. This would be an extremely time and cost effective method of site characterization.

The measurement of the spectral characteristics will be analyzed in four different areas.

1. The soil and groundwater samples will be analysed continuously by utilizing the Atomic Absorption Spectrophotometers of the Department of Physical Geography. This method of analysis will provide measurements of the quantity of accumulated and migrated heavy metals. This will allow the determination of areal impact of the mud-deposits situated near the wells. The existing ground water well-system will be extended by 5-6 m. The ground-water level will be continuously measured and the samples will subsequently be

analysed every second week. This will result in approximately 2000 laboratory analyses over the three year life of the project.

2. Field spectroradiometer AVS-2000 (financed by OTKA) will be used to measure ground spectral reflectance. The use of these multiband instruments will allow us to detect the reflectance of 2,5 nm wavelength regions characteristic of reflectance of the study area's surface (200-1100 nm). The reflectance of soils found in the surrounding area of test waste disposals will be measured *in situ* and in the Laboratory of the Department of Physical Geography. This will establish the background levels. The data will be correlated with the results of the soil chemical analysis. Prior studies have clearly demonstrated that this method can identify and delineate contaminated soils and vegetation.

3. Hyperspectal imaging is not a common method for site characterization due to the high capital costs of the equipment. The large extent of the oil field (6*4 km^2), however, makes it necessary to apply areal remote sensing techniques. There are several government and research agencies who possess the necessary equipment, hence we included such agencies as project partners. The data acquisition is approximately the same cost as standard multi-spectral data. We are planning only two measurement campaigns, at the beginning and at the end of the program, to demonstrate the applicability of this technology. With the current imaging systems we can acheive 3-5 m geometric resolution while spectral imaging provides 1-12 nm resolution.

4. The wells within the oil field and pumping stations are linked by high temperature/pressure pipelines containing hydrocarbons. The pipeline is in poor condition and has developed numerous ruptures resulting in the contamination of several 100 m^3 of soil. The cost of remediating these areas would be in the range of tens of million of forints. The Hungarian Oil Company regularly monitors the pipeline system via the acquisition of aerial video. Unfortunately, this method does not provide reliable results. Therefore, we propose to expand the monitoring to include thermal analysis of the near-well disposals of the pipeline system. This would allow us to accurately monitor the surface temperature with an areal thermoradiometer. These sensors are able to detect 0.1C degree differences in temperature. This would allow the immediate identification of any pipeline ruptures. This would also be able to detect the detioration of wall thickness in surface pipelines.

The development of hyperspectral spectroradiometry includes the development of new sensors, the establishment of calibration systems, and the investigation of the spectral characteristics of soil and vegetation in Europe. Both field and laboratory based radiometric measurements have been used to investigate the potential applications of this technology. An ASD FieldSpec detector was used to measure the spectral reflectance of various contaminated targets in wavelengths ranging from 0,4-2,5 μm in the EGO (European Gonimeter) project. In the IRSA (Institute for Remote Sensing Application), a GER IRIS spectroradiometer was used to measure petroleum contamination in soils. The results of the above-mentioned studies, clearly demonstrated that petroleum contamination of soils can be detected by hyperspectral image processing, particularly in wavelengths surrounding 1.7 μm. There are existing airborne sensors which measure spectral reflectance in this wavelength (DAIS, AVIRIS, MIVIS, etc.). Sensors which measure narrow bandwidths within the reflected infrared spectrum are able to discern between healthy and stressed vegetation. Results from previous applications using the MIVIS sensor were able to detect both petroleum and heavy metals contamination in bare soils and grasslands.

In 1996 the measurements were conducted within the framework of an EGO project under different conditions, which were similar to the parameters of Multi-angle Imaging Spectrometer (MISR). The MISR will be launched on the American EOS (Earth Observation Satellite) in 1998.

How will the results contribute to the solutions of industrial, environmental or security-related problems?

The expected results of the proposed Research Project will be used to develop a greatly improved method of site characterisation and monitoring. The resulting methodology will allow expedited and cost effective regional characterisation and monitoring. The resulting technology will be useful for: detection and assessment of industrial contamination, detection of former military and industrial operations, determination of impacts from industrialisation and urbanisation, and potentially the location of hazards such as land mines. The immediate contribution will be the characterisation necessary to assess and remediate the largest oil field in Hungary. The project will not only characterise known contaminated areas, but will serve to detect unknown contaminated areas (soil, vegetation, and groundwater) within the study area. The use of remote thermal sensors will allow the detection of leaking pipelines and storage units. This early detection could prevent further contamination due to the unchecked outflow of undetected contaminants into the surrounding media. The project results will include maps depicting the locations and contamination extent of the near-well disposals and detailed GIS based modelling results depicting the above and below surface contaminant transport. The Hungarian Oil and Gas Company Ltd. will use these data sets to develop the most efficient and effective remediation strategy for the contaminated regions. The Hungarian Oil and Gas Company Ltd will finance the site remediation.

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EVOLUTION OF GREEN AREAS IN KOLOZSVÁR (CLUJ NAPOCA, ROMANIA)

Géczi, Róbert – Bódis, Katalin

When mentioning the system of green areas we refer to all the vegetated surfaces of a town. The system consists of town owned playgrounds, cemeteries, and sports fields; private owned gardens; and forests, orchards, and arable lands around the town. The advantages of these units are well known (improvement of town climate, disintegration of organic pollutants, filtration of contaminated waters, protection against noise). These green areas located in the matrix of built up environment, functioning as ecological islands and corridors for the elements of natural flora and fauna that colonise urban areas. The success of the populations of colonising species in finding proper habitats in the town to where they can settle is determined by the existence or absence of vegetated areas. The process is greatly advanced by ecological 'green' corridors, links, undisturbed refuges, and the lack of strong competition, that is a characteristic of urban environment (*Gallé 1997*). The adequate system of green elements may also involve narrow green strips on the edge of arable lands, slopes of dams, banks of rivers and canals, and grass covered roadsides. Thanked to these the enabled immigration from core territories may prevent the decrease of biodiversity and stability (*Kubes 1996*). Nevertheless, at the same time these green areas represent the most conflicted zones of a town, and the consequences of human load can be experienced on these territories the best.

The development of the green area system of Kolozsvár

The present species and formations in Kolozsvár are in an inevitable connection with the development of green areas, and the changes of land-use within the town. The first information on land-use change was from the Roman times (2^{nd}-3^{rd} centuries BC.) when in the vicinity of the antique Napoca vineyards were cultivated on the southern slopes of the Hója Mt. (*Ferenczi 1947*). It was a characteristic of Romans' land-use that they did not appreciate much untouched nature, and believed that the ideal sphere of farming is the well-ordered countryside around the town (*Montanari 1997*). The first change in the town's haemerobia level can be placed to this era when the transition from natural to semi-natural, then to human biologic stage occurred, parallel with this transition the increasing human impact left more and more marks on the environment. At this time there was no green zone in the town, and the ratio of built up land was 75-100 %.

The earliest written document that mentions the town is from 1213, when due to its renewed castle Kolozsvár became a centre of the Hungarian royal county system. Kolozsvár got its township from Charles Robert in 1316. On the basis of an 1405 act of Sigismund the settlement beside the River Szamos became a royal free township. During this period the castle and the borough, surrounded by a wall, melted into one body. In the previous centuries there was a village in the place of the borough, that became a fortification (Óvár), strengthened by square-shaped battlements, after the Tartar invasion. At this point the territory of the protected borough was 7 ha (*Gaál 1995*).

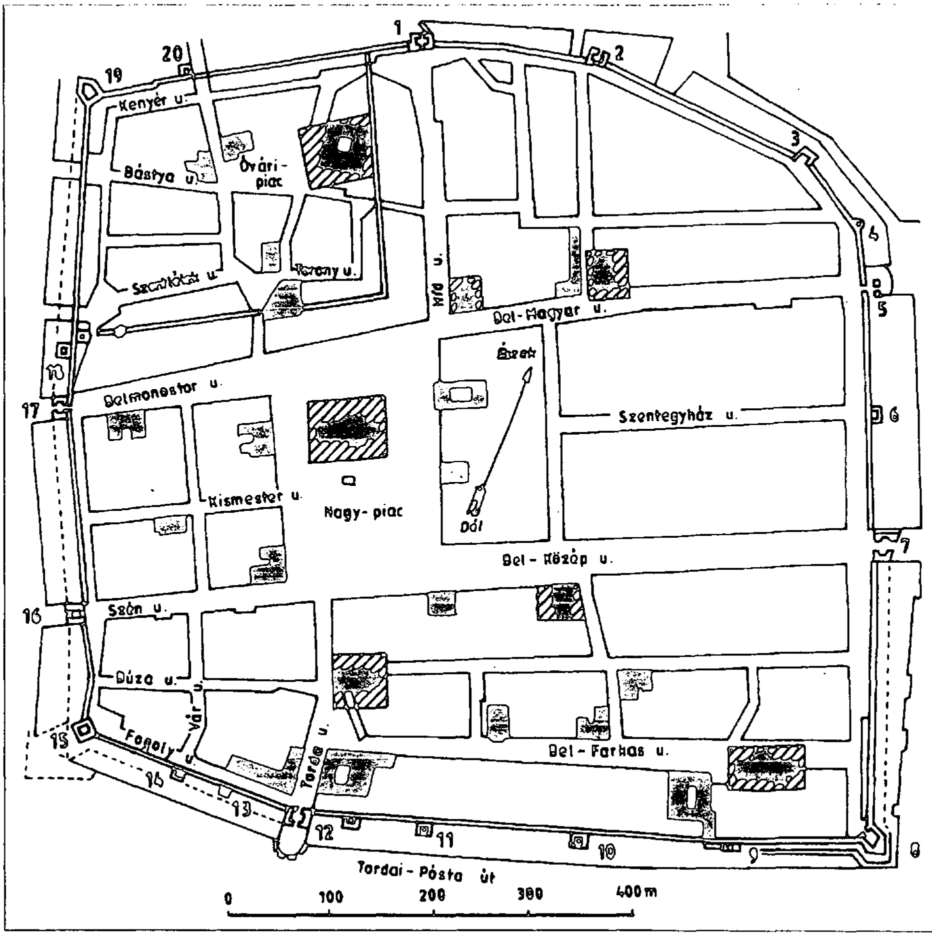

Figure 1 The ground-plan of Kolozsvár in the 16th century (numbers indicate town gates)

It is a question, why did a regular street network, that remained till the 20th century, evolve in the settlement out of the Óvár district during the second half of the 14th century. The orderliness of the German and Flemish citizens could have been one reason for this, since, the ground-plan of Beszterce, that was found by Saxons, is very similar to that of Kolozsvár. However, it is more probable that the role of geographic and economic conditions were stronger, because the Millrace [Malomárok] –beside which a main market road stretched–, that supplied the borough with water, with its W-E flow, and the slopes of the Házsongárd determined the northern and southern boundaries. At the beginning of the 15th century there was a demand for strengthening the new enlarged town centre of 47 ha with walls and battlements. As a result of this, a rectangular-shaped fortification was constructed, and its southern wall was parallel with the third terrace of the Szamos, and the south-eastern battlement of which is still standing. At this time the length of the town wall exceeded 3 km, and it was protected by 20 gate towers and battlements. This was a prospering era of building bourgeois, renaissance, 15^{th} century houses. The 16^{th} century street network was roughly the same as now, the only exception was the presence of a surrounding street just inside the wall, that was demolished, with the street as well in the post-liberal era. The last gate towers were destroyed in 1868. The street structure inside was determined by the old castle walls, then by the Main Square. The existence of walls significantly limited town space. Similarly to other medieval and renaissance towns, there was hardly any green spaces inside the town wall (*Fig. 1*). On the copy of Georg Houfnagel's copper engraving, that was based on the 1617 drawing of Egidius van der Rhye, the Flemish painter, and depicts the town from the South, the forests on the hills out of the walls, and the vineyards on the southern slopes are illustrated (*Fig. 2*).

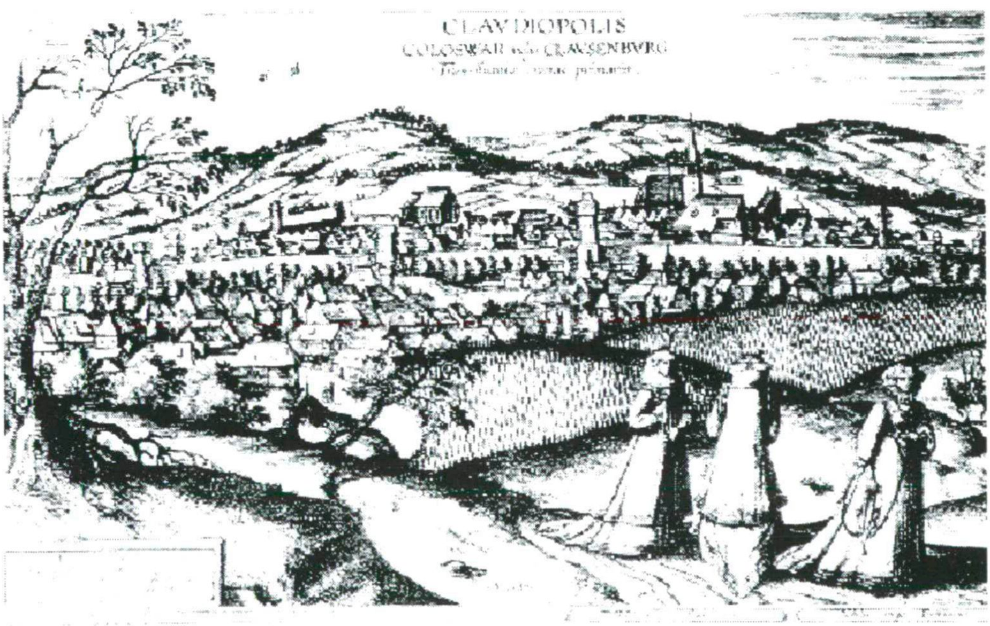

Figure 2 The vegetation around the town (Houfnagel's copper engraving)

The existence of hidro- and higrophylous vegetation on the floodplain is proved by an order of the town council that forbade the cutting down of willows in order to protect the very small-sized green areas. There could be vegetable gardens and orchards outside of the wall, since, a 1552 order of the town leadership declared that those who damage private orchards must be punished exemplary.

The method of use of lands outside the town walls can be illustrated by a 1610 town meeting regulation that due to strategic reasons prohibited landowners from establishing houses or any other buildings, from planting any kind of trees, and allowed only the cultivation of vegetable gardens in the place of previously demolished farms located in front of a town gate (*Jakab 1888*). The main reason for this act was to prevent the enemy to find shelter in the buildings.

This might explain why the agricultural type settlement evolving in the 16th and 17th centuries outside the walls was at least 200 m far from the borough (*Fig 3*). The spatial fusion of the two zones of the town (the industrial, commercial, urban zone and the stock holding - agricultural zone), i.e. the districts inside and outside the wall was started from the end of the 18th century, when the significance of town walls completely ceased.

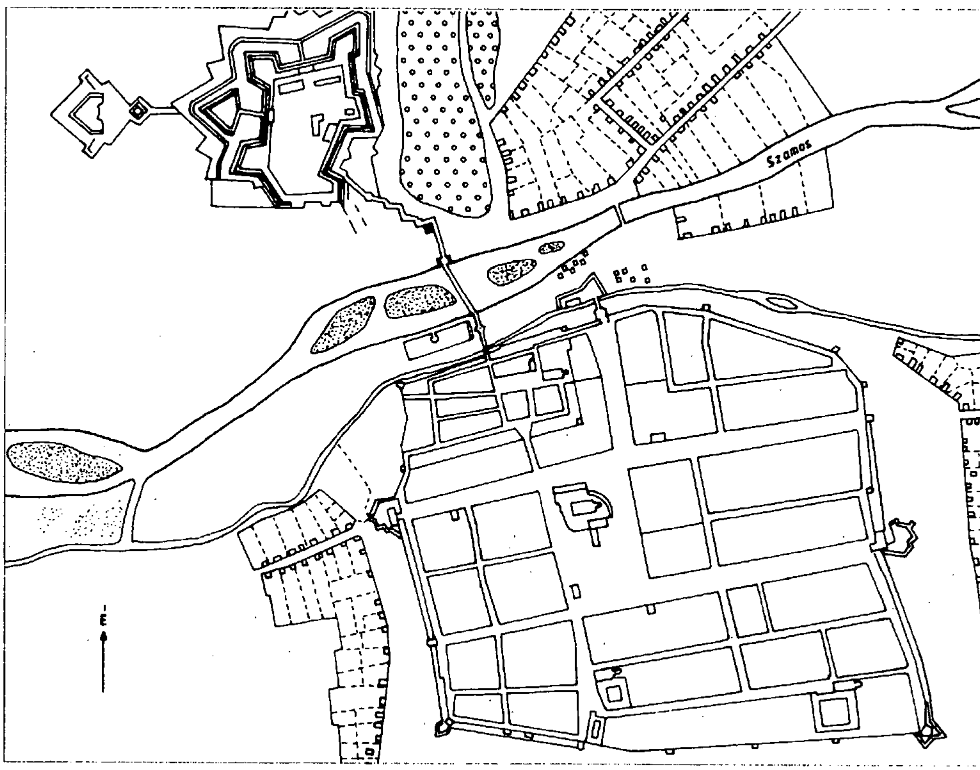

Figure 3 The ground-plan of Kolozsvár in the 18th century

In the 16th century the cemeteries of the churches became overcrowded within the town, therefore, in 1586 the "outer great hedge-garden" was ordered to transform into a graveyard, that later became the famous cemetery of Házsongárd. The transformation implies a rational town planning, since another act ordered that from then on everybody must be buried into the new graveyard. Among others it was also determined that the graves must be placed in a certain order, because the scattered and unsystematically dug tombs "have already started to fill up the huge area" (*Gaál 1992*). To maintain the order, on the basis of a judiciary decision an inspector was appointed, who got the power to point the place of new graves. Thus in the 16th century Kolozsvár there was an existing town management concept, which by establishing a systematically parcelled out cemetery with a path network determined the townscape and influenced the structure of the town.

The 18th century brought a new prospering period for the town, and as a result of this new orders were passed regarding green spaces and the way of land-use: the Citadel was completed in 1723, and to serve it, the first bridge of Kolozsvár, named as the "Germans' plank" was built, as well. The territory that lay South of the River Szamos, between the town wall and the citadel, and formerly gave place for vineyards started to be built up at this time. In 1789 a regulation orders the burghers to build pavements beside their houses, and eventually in 1790 the territories outside of the wall were parcelled out and sold. In the same year the idea of demolishing the houses around the church of the Main Square arouse, since "the church was a national heritage" (*Lázár - Kusztkó - Dobál 1906*). In 1820 the destruction of the town wall started, because the rational thinking of the era claimed them invaluable and useless, and in addition it could be recycled as a building material. At the same time the streets were paved, and the major streets were lightened with oil lamps.

On the basis of contemporary photographs, in the middle of the 19th century the planting of trees on streets and other public places became a generally accepted action. In 1839 the streets of the downtown were broadened, and trees were planted on the Main Square. A photograph, taken in 1870, shows an enclosed group of trees South of the church on the Main Square. Based on a 1879 decision of the town council, tree plantation began on the streets and public squares.

The united town embellishment concept was worked out during the first mayorship of Károly Haller (1884-1886). The plantation of trees on the formerly pitted, muddy Trencsin Square, that is on the 2nd terrace, was also started at this time. Later the square became a popular walking place of the uplifting uptown (*Lázár - Kusztkó - Dobál 1906*). The afforestation of the "citadel's treeless, grassy plateau", the establishment of the watermains of the town, the launching of tree plantation on streets and squares, the creation of the plans of a slaughter-house, and the annexation of the adjacent village, Kolozsmonostor to the town are all can be connected to the name of mayor Haller. During this period the remaining natural vegetation in the town was replaced by conifers and thermophilous trees, which were to satisfy the aesthetic, and recreational demands of the developing bourgeoisie. At Kolozsvár the highest green space/head ratio occurred at the end of the 19th century, when 47 % of the town of 2849 ha was covered by vegetation (*Jakab 1888*).

Besides, the decoration of the Main Square, the extension of tree plantation, the demolition of town walls, the embellishment of the newly gained squares, the opening of new streets, and the transformation of the citadel into a walking place that is worthy of the town were also decided (*Kőváry 1886*). In 1895 the Main Square gains its present face. Until 1898 pavements of 5 m width and granite cart-roads of 12 m width were constructed, a gothic iron railing of 85 cm height was built around the church, and the first still present species of: *Picea excelsa, Abies alba, Abies concolor, Taxus baccata, Picea pungens var. argentea,* and *Thuja orientalis* were planted.

The establishment of a "Kolozsvarian walking place", the present Walking Square, was brought up at the beginning of the 19th century. Already in 1837 it was decided that a "park of French or English style" would be established on the floodplain of the Szamos in the place of a marshy field (Hangyásberek) that connected the river with the Millrace. On the territory several channels, lakes, and swampy areas were located, that eventually disappeared during the establishment of the Walking Square. From the natural vegetation (probably a *Salcetum-Populetum-Alnetum* association was dominant) of the marsh a few pieces of *Tilia cordata, Populus tremula,* and *Alnus glutinosa* were kept. The main axis of the Walking Square was formed by a promenade, bordered with four rows of *Aesculus hyppocastanum*. Usually, the vegetation of parks and walking squares were planned by architects, and as a result the planted trees often did not find the adequate conditions, and died. The same happened in the case of the Walking Square, since the 300 Picea excelsa, planted in 1873, could not bare the high level of ground water (2-3 m). Based on contemporary documents, "flower-, georgina-, and rose-groups" decorated the Walking Square (*Kõváry 1886*).

In the 19th century a general water regulation plan was worked out, on the basis of which the Millrace was established. Its water was used, among others, to supply the brooks running along the promenades of the Walking Square.

An important part of the green area system of Kolozsvár was the ornamental gardens of the aristocracy. It was not a baseless claim that "Kolozsvár is the town of gardens"*(Kõváry 1886*). Some of these were: the Mikó Garden and the Jósika Park that still function as green areas, the gardens of Baron Kemény at the eastern part of the town, the Veress Garden at the corner of the Walking Square and the Fürdõ Street, the Haller and Nemes Gardens on the Monostori Road, the Bánffy Garden near the Walking Square, and the garden of Earl Kendeffy on the Külmonostor Street, and besides, the Ábrahám, the Apor, the Balla, the Bernáth, the Székely, and the Barátok Gardens (*Szabó 1946*). Till 1837 the largest public garden of Kolozsvár was the "royal garden" that was functioning as a game reserve and walking square, at the eastern, south-eastern part of the town, just outside of the town wall, from the 18th century (Gaál 1992) (*Fig. 4*).

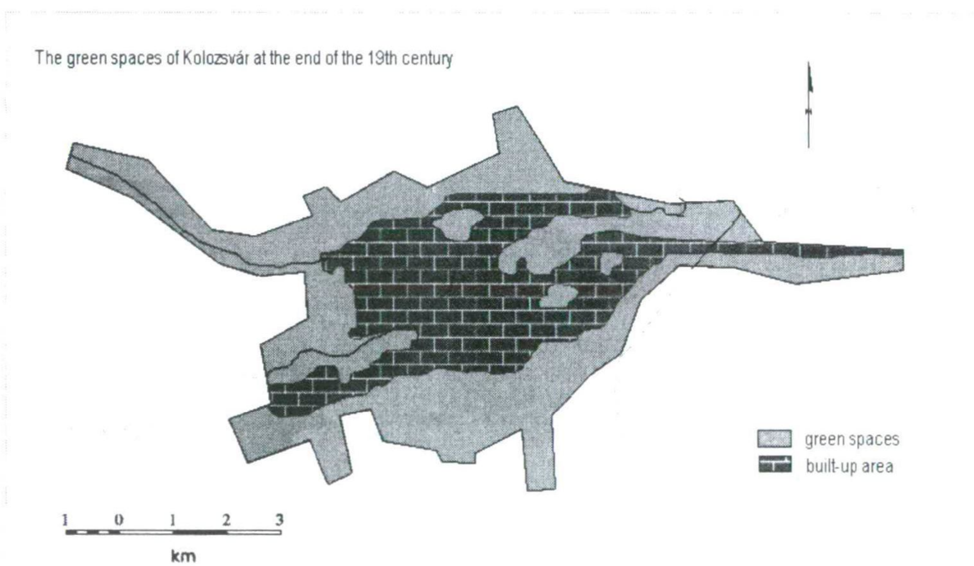

Figure 4 The green spaces of Kolozsvár at the end of the 19th century

The most famous garden was the Mikó Park, the area of which was 8 ha, and that became a botanical garden later. Now it gives place to the students' quarter, the buildings of the Geographic Faculty and the Zoological Museum. The remnants of the natural vegetation (*Robinia pseudoacacia, Acer platanoides, Acer negundo, Abies alba, Gleditschia triacanthos*) can be found on its present territory. In 1869, West of the Mikó Garden, also on the III. terrace, the park of the Agricultural Academy was established. In the Northeast, on the upper most terrace of the Szamos, a tree nursery was opened, that is functioning at the present still as a green area, its name is Palocsay Garden. In 1881 on the territory of the Óvár Market (Karolina Square) another small garden was established, though, by now only a few ten m^2 has remained from it. Considering the fulfilled plantation programme, we can state that the town of Kolozsvár had large vegetated areas of recreational function at the turn of the last century.

At the beginning of the 20^{th} century a new district, an industrial quarter began to develop in the eastern part of the town. First the Renner leather factory and the Reitler match factory were established. The location of the industrial quarter refers to a rational decision, since the dominating westerly winds and the Szamos, that flows eastward, are capable of clearing away pollution from the town. Parallel with this on the III. and the upper most terrace, the officials colony was started to build up. This quarter has preserved its suburban character up till now.

The next larger green space was established in 1934, when another marshy field (Fásberek) on the floodplain of the Szamos was converted to a sports park. In the park of 30 ha *Thuja, Picea, Liriodendron, Abies, Aesculus* tree species, and *Salvia, Coleus, Canna, Dahlia, Narcissus* herbs were planted beside the native vegetation (*Ligustrum vulgare, Euonymus verrucosus, Lonicera xylosteum, Sorbus torminalis, Fagus silvatica, Acer campestre, Acer pseudoplatanus etc.*). However, according to the opinions of experts, the sports park's plant composition "is not satisfactory, the sport fields in the park are placed irregularly, the size of promenades is not adequate" (*Fekete 1995*). The territory, functioning as a green zone and recreational park, is beneficial concerning climatic effects, since, the dominating westerly mountain and valley winds can transport fresh, clean air toward the centre of the town. The small park that is wedging between the Óvár and the Millrace was established in the 1960s. The park has strongly deteriorated, its almost non existing grass land community is complemented with some very endangered (due to household pollutants) urbanophiton tree species (Acer negundo, Aesculus carnea, Salix babilonica, Prunus pissardi), and some shrubs that are the elements of the spontaneous flora (Sambucus nigra, Viburnum lantana), as well. The Walking Square and the above mentioned park to some extent equalise the urbanisation and industrialisation processes characterising the eastern floodplain of the town.

Till the 1940s and 1950s, in the eastern part of the town on the territory of the formerly called Tóköz swamps and lakes were located. The area that was occupied by industry was functioning in the 1950s as a dump, in order to fill the hollow, thus, the swamp and the lake disappeared completely. According to Nyárádi, the sometimes-natural area was „one of the swamps of the freshest vegetation that was a lake until peat formation began. Its western end is covered with a little water" (*Nyárádi 1944*).

Due to the nationalisation in 1948, the architects could plan according to their own pleasure, often they did not consider the demands of transportation and commerce, therefore, a poor and short term spatial planning was accomplished. The situation of green areas was the same, since, with the exception of the sports park that was established in the place of a floodplain forest in 1955, the total size of vegetated territories has constantly decreased.

At present, the size of urban area/head does not even reach the half of the recommended 220 m^2 EU value either, while in case of the green areas instead of the accepted 40 m^2, the values in 1998 and 1999 were 8 and 7 m^2, respectively.

Concerning the development of the green spaces of Kolozsvár, the following conclusions can be drawn:

- In the medieval town, that was extending mainly over the floodplain and the so called town terrace, and was surrounded by a town wall, there was nothing like a vegetated area, moreover, even single trees were missing. Outside of the walls, beside the native vegetation, represented mainly by deciduous trees, gardens and vineyards were existing.
- A planned and careful green space maintenance was carried out in the 19^{th} century. The green spaces reached their greatest extension. The 50-60 m^2 green area/head ratio can be explained with the high number of „aristocratic gardens".
- After World War II. these gardens and the forests around the town were eliminated, and orchards and urban environment took over their places.
- From the 1960s and 1970s, but after the privatisation more significantly, the extension of green areas has decreased. The areas inside and outside of the town have become built up lands, what have brought several further conflicts.
- The number of neglected small-sized areas is increasing. At present, the area of waste territories occupied by ruderal vegetation is 798 ha (*Fekete 1995*).

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FEATURES OF THE SUSTAINABLE FOREST MANAGEMENT THAT CAN BE IMPLEMENTED ON THE LAND OF THE PROJECTED PROTECTED LANDSCAPES IN WESTERN MECSEK

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Abstract

The sustainable forest management is part of the sustainable development, which is an important task nowadays. Principles of the sustainable forest management have to apply on the projected Protected Landscapes in Western Mecsek, when these protected landscapes will formed. The goal of it is to preserve the sylviculture under the nature conservation, and to keep the forests of the area in a nature-close state.

Introduction

The projected Protected Landscapes in Western Mecsek includes major part of Western Mecsek. Its southern part basically consists of sandstone, while its northern part is dominated by karstifying limestone. At present four nature reserves can be found within the land of the planned landscape-protection area: the Jakab Hill, Melegmány Valley, Pintér Garden and the Cave of Abaliget.

On FAO conference held in Buenos Aires in 1972 there was set the goal of achieving the realisation of the triple function of forests, which includes the achievement of production/management, environmental protection and recreation/public welfare goals. As long-term objective the sustainable forest management was aimed at, which is important part of the sustainable development of the landscape.

Hungary made the sustainable forest management a principle to be followed officially in the Act on Forests No. LIII. of year 1996. According to the act the sustainable forest management means that the forest is utilised to such extent, which ensures the conditions of management for the future generations too, in a way, that the forest preserves its great biological variety, nature-closeness, recurring ability, vitality, as well as fulfils its triple function of production, environmental protection (preservation of the ecosystem, protection of the soil and climate), and recreation.

Sustainable forest management methods

Forest management is a dual activity, which contains both the sylviculture and the forest use. The former one means timber production and plant protection, and the latter one means wood-felling and cutting, secondary use, and background infrastructure.

The most important principles of managing forests being under nature conservation are as follows [1]; [2]:

- Ensuring the survival of the natural forest associations.
- Performing regeneration from seeds in natural way instead of regeneration from stump by sprouting.
- Applying native species of trees.
- The area of final wood-felling may not exceed 10 hectares.
- Clear-felling is allowed only at places, where there is no other way for regeneration, and its area may not exceed 5 hectares.
- Cutting age must be raised.
- The use of plant-protecting agents must be restricted.

Forest management has important environmental protection duties, which go beyond nature conservation [3].

Forests extract considerable amount of *carbon from the air.* Beside carbon fixation forests also *play important role in oxygen production and dust deposition.*

Soil conservation, which mostly means the protection against erosive damages, is important duty of the forests. According to it, cutting age is postponed as long as the stock is able to ensure the protection of the soil, which is about 100 years.

The realisation of *landscape protection goal* means the preservation of the original view of the landscape primarily by *avoiding clear-fellings.*

Forest management can also be connected to *settlement protection.* Forests *moderate the weather extremities, improve microclimate, reduce air pollution,* and furthermore the field protecting forest belts and urban forests protect the settlements.

Karstic water protection may be important part of protection. This comes to the front to a greater extent in Western Mecsek, where major part of the planned landscape-protection area consists of karst.

From water protection aspect within the land of Western Mecsek there can be hazard points the municipal waste of Orfű and Abaliget, as well as the smaller extension plough-lands of their environment and the horse farm lying beside Orfű. In addition, the Petőcz-puszta works and air-shaft of Plant No. IV. of Mecsek Ore Mines should also be considered as pollution source. However, its significance keeps on decreasing since the reduction of uranium mining.

Future directions of forest management

Formerly, the basic objectives of forest management were increasing the productivity of the forests and improving the timber quality. The *duties of* the sustainable or in other words *long-lasting and environmental forest management* can be classified around three fields [4]:

1) *Surveying the environmental hazards* that threaten the forests and *reducing* the expected *damages*. Such hazards can be the forest destruction, air pollution, forest fires, diseases, etc. For this survey the natural and deteriorated state of the forests should be recorded, which provides a base for comparison for future investigations. The determination of the natural state is based on the individual characteristics of the plant species, which compose the vegetation type (eg. natural species or species referring to degradation). On this base rating the naturalness values from 1 to 5 the following categories were set up: artificial, strongly transformed, moderately transformed, nature-close and natural forests [5].

2) Reviewing and *developing the technologies* and processes applied in forest management *in order to decrease the damages* the management may cause.

3) *Improving and spreading those forestry methods that are useful for environmental protection, environment management and environment development.*

The most important duty is *to transform the traditional management into nature-close management* [6]. There must be given up the practice of using the forest rarely, but by cutting large volume of trees then.

Forest parts of the same age are not desirable, 40-50 years age difference is desirable from the aspect of both ensuring even timber output and landscape aesthetics.

Occasionally there can be applied the *selection felling operation*, which has the advantage that from year to year getting back to the forest part only the volume equal to the annual increment is cut.

It is important, that the *wild beasts should not exceed the alimenting ability of the forests.*

There must be maintained the *recreation function of the forests*, by restricting its environment burdening effects, which means eg. that car traffic must be driven out from the forests.

For applying these principles in practice, there is a need for landscape management, and within it for managing the forest landscapes. The forest landscape management is the management approach of the forest landscape, which includes the communal and ecological interests, such as preserving biodiversity, the production-capacity, health state and vitality of the forest ecosystem controlled by the structure and dynamics of the landscape [7].

The principles of the forest landscape management include the involvement of the society (users of the land and decision-makers), as well as the extensive consideration of the ecosystem's aspects. The internal structure, rules, behaviour of the forests must be examined dynamically, which creates the balance among the physical, biological and human dimensions [8].

Features of the nature-close forest management in the Western Mecsek

Within the projected Protected Landscapes in the Western Mecsek at present there are two major areas that enjoy protection, the Nature Reserve of Jakab Hill and the Nature Reserve of Melegmány. On these areas due to the protection, the wood-felling and cutting is restricted even at present, which meets the requirements of the nature-close forest management. Apart from the protected areas, the wood-felling is restricted altogether in 146 other forest parts. The reason behind it is partly the protection against the erosion on the steep slopes, which primarily concerns the areas lying to the south from Jakab Hill and to the north from Cserkút. The strengthening of the gullies is connected to the protection against erosion. It provides the main reason for restriction in the case of Zsuppon-parlag that is located to the north from Misina. Thirdly, for ensuring the sport, turistic, holiday and recreation goal the wood-felling is also restricted altogether in case of 127 forest parts. The achievement of this goal primarily concerns the so-called "urban forests", which means the southern side of Misina and Tubes lying to the north from Pécs and the Éger Valley. The Cigányföld located to the east from Orfű and the area lying to the east from Melegmány are restricted for similar reasons. These restrictions serve the realisation of environmental and recreation goals included among the goals of the sustainable forest management, while the non-restricted areas serve the realisation of production goals.

By extending the protected areas the restriction of wood-felling will concern larger area, however the establishment of the landscape-protection area does not mean the total cessation of production, but will imply the obligation of applying the environment saving technologies widely.

One of the reasons behind establishing the projected landscapes is the naturalness state of the forests covering the area. The forests are in nature-close state, where the human intervention is not considerable.

In Western Mecsek we can distinguish four major *natural forest associations, beech-groves, hornbeam and chestnut oak-groves, chestnut oak-groves and Turkey oak-groves.* In the case of these natural forest associations management is done according to the considerations of the nature-like forest management. In such cases, the forest is managed by imitating the processes taking place in the nature. Wood-felling and cutting, caring and forestation are also made this time, but their intensity is moderate, their means and technologies are gently, and returns are frequent.

The beech-groves, hornbeam and chestnut oak-groves, chestnut oak-groves are regenerated in natural way, but the Turkey oak-groves are treated with clear-felling and artificial forestation, since they get renewed very poor in natural way. There are such forests too, which can be considered natural, but are *not suitable for the habitat's potential.* Most of them are unsuccessful or consequence of a missed intervention, these are the so-*called spoilt forests.* This problem can be cured by structural change, or post-clear-felling artificial regeneration. In Western Mecsek the area of these forests do not reach 100 hectares.

In Western Mecsek considering the way of regeneration the following area rates can be defined in terms of the natural forests according to the forestry data:

Forest type	Natural	Artificial	Total area
Beech-grove	99	1	32
Hornbeam and chestnut oak-grove	77	33	31
Chestnut oak-grove	81	19	16
Turkey oak-grove	0	100	10

Table 1 Distribution of the regeneration methods in the natural forests within the area of Western Mecsek (%)

It can be seen from the table, that *in the case of forests occupying near 90% of the area the natural regeneration is prevailing.* The only exception is the Turkey oak grove that is difficult to regenerate. Furthermore, it can be also seen that almost the entire area of Western Mecsek (89%) is covered by the natural forest associations mentioned in the table. In the remaining 11% there are also natural associations, such as chine forest or karstic bush forest, and the other hard leafy forest spots that cannot be considered natural on the area counts only for a small proportion.

Beside the naturalness index *the nature-close state of the forests of this area is verified by the chemical reaction, lime and heavy metal content examinations of the soil, the vegetation analysis based on ecological indecies, and the examination of the comparison of the prevailing soil types and flora. Figure 1* illustrates the map that was made as result of this comparison.

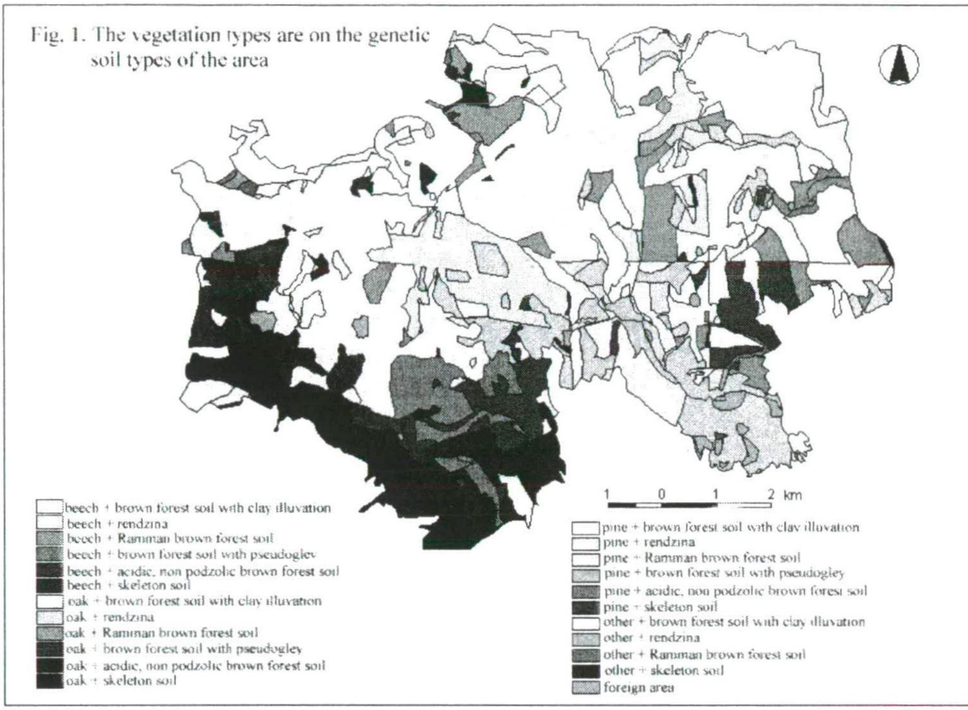

Figure 1 The vegetation types and the genetic soil types

By analysing the map it can be stated that *beech-groves* appear with the largest extension on the area, *on brown forest soil with clay illuvation*, majority of which can be found on the northern, *karstic area*. However *beech-groves and oak-groves* are climate zonal associations that can be found on all prevailing soil types of the area. *Their spread is connected rather to the exposure and slope conditions*, than to the soil types.

On the southern part of the area, primarily connected to the *southern exposure*, oak-groves can be found, mostly *on strongly acidic, non-podsolic brown forest soil* that formed on sandstone. The *skeleton soils* are connected to steep slopes, *areas with large angle of slope* (eg. southern side of Jakab Hill), where due to the exposure partly *oak-groves*, and due to the shallow thin tilth partly *planted pinewood* can be found.

The *rendzina* connected to the limestone appears on the *northern areas*, mainly with *beeches*. On the sandstone of the southern part primarily pseudogley, and strongly acidic, non-podsolic brown forest soils were formed, to which depending on the exposure oak-grove and beech-grove associations connect.

Regarding the flora, the pine spots and the Ramman-type brown forest soil appears in small extension. The pinewood is mainly planted bog-spruces, which do not belong to the native associations of the area. Their plantation served the protection against erosion on the steep areas, therefore their presence cannot be considered harmful. However, on those areas where the soil type and the angle of slope enable it (see: "urban forests"), it is reasonable to change them anyway.

Conclusions

Elaborating the principles of the sustainable forest management and applying it in practice on the protected forest areas, especially on the environment-sensitive karstic areas constitute an indispensable part of the sustainable growth, which is frequently mentioned nowadays.

- The *projected Protected Landscapes in Western Mecsek* is almost entirely *covered by forest*, the *majority of which is in nature-close state*. It is especially true for the northern, limestone composed karstic part of the area, which is free from the turistic overload of the "urban forests" located near to Pécs, and the landscape-strange pinewood plantations made for the purpose of protecting the steep areas.
- From sensitivity aspect, *it is the karstic part of the area* that deserves larger attention, since at each points of the world, including Hungary too, a distinguished interest is given to the karstic areas, which are *especially sensitive* to the harmful external influences. This sensitivity supports the demand of the karst of Western Mecsek on protection, which is also justified by the naturalness state of the area's forests. On the triassic limestone of the area mainly brown forest soil with clay illuvation and rendzina can be found, to which prevailingly beech-groves and oak-groves connect mixed with hornbeam. These associations meet the conditions created by the lithographical, pedological and climatological characteristics of Western Mecsek.
- The consideration of the production, environmental and recreational triple function of the sustainable forest management in the protected parts of the area is already part of the present forest management. *The projection of the three functions to a larger area*, that the establishment of the landscape-protection area makes necessary anyway, *requires the improvement and spread of the nature-close methods and their application as wide as possible*, from the forest regeneration with native species up to fulfilling the settlement protection duties.

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COMPARATIVE ANALYSIS OF SOME SOIL CHARACTERISTICS ON BÜKK AND AGGTELEK KARST (HUNGARY) WITH SPECIAL REGARDS TO ORGANIC MATERIAL

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Summary

In the essay I study the pH, carbonate content and organic matter content of soils in karst areas. In the last ten years the investigation of soils in Hungarian karst came into limelight. The soil has an important role in the ecological system because it can buffer the harmful environmental effects that take effect quickly. I examined an 8-8 km^2 part of the Bükk Plateau and Aggtelek Karst. Both areas are protected: they are in the Bükk National Park and in the Aggtelek National Park. The soil samples were collected from areas that represent different ecological conditions: beech forest, oak forest, pine forest, beech with pine forest, beech with oak forest, seedling nursery, stubble and open field. During this investigation - among others - the pH(H_2O), the pH(KCl), the carbonate and organic matter content of 185 soil samples were measured from 48 sample sites.

Introduction

The investigation of soils that occur on karst has great importance. The soil has an important role in the ecological system of karst areas because it can buffer the harmful environmental effects that take effect quickly (*BÁRÁNY, I. – MEZÕSI, G. 1978, BÁRÁNY, I. 1980, ZÁMBÓ, L. 1986, BÁRÁNY-KEVEI, I. 1987 a, 1992*). Since the soils of karst areas are generally not used for agricultural purpose, we have only a few measured data and results.

I investigate the soil nutrient system and heavy metal content of soils in some Hungarian karst (Bükk Mountains, Aggtelek Karst, Mecsek Mountains) in different ecological conditions. For this reason we need to know the pH, carbonate content and organic matter content of the soils as well. On the one hand they are important because of the nutrient system and the mobility of heavy metals in the soils. On the other hand the pH of soils is in connection with the buffering capacity. A reduction in soil pH is often the best indication of loss of buffering capacity of a limestone soil. The acidification of soil causes an increased bedrock solution (since the acidity of the percolating water determines the solutional rates of the bedrock) and the loss of aggregate stability. These together lead to an accelerated soil loss because of the increased erosion. (*GILLIESON, D. 1988*).

I study the connection between pH, carbonate content and the limestone fragment content of soils in the different ecological conditions. The other subject of this investigation is the organic matter content of the soils: the connection between the different plant-covering, the human activity and degradation. For this reason I collected some soil samples along the same slope profiles. There are two slope profiles on Aggtelek karst (the 19-18-17.

and 20-21-22. Sample sites belong together) and three on Bükk Plateau (the 20-19-18-17., 21-22-23. and 24-25-26. Sample sites belong together).

Methods

I examine an 8-8 km^2 part of the Bükk Plateau and Aggtelek Karst (between the villages Aggtelek and Jósvafő). The soil samples come from different ecological conditions: beech forest, oak forest, pine forest, beech with pine forest, beech with oak forest, seedling nursery, stubble and open field. The soil samples are from depth of 5-10, 10-20, 20-30, 30-40 cm.

During the examination I measured the pH in distilled water and in 1 M KCl solution by digital pH-meter. I calculated the ΔpH (=$pH(H_2O)$ – pH(KCl)) of soils as well. Scheibler-calcimeter was used to determine the carbonate content of soils. The organic matter was oxidized in acid solution by $K_2Cr_2O_7$ and measured by spectrophotometer.

Discussion

The detailed description, datas and figures of the carbonate content and pH of soils are presented in my former papers (*ZSENI, A. 1999 a, b, c*). The carbonate contents are mostly below 1 %, they are often 0 %. According to this the pH of the soils is also lower than we expect it in the case of limestone bedrock.

In both areas the soils are mainly acid and weakly acid, only 1/3 part of them is neutral and weakly basic. The pH of soils mostly increases with depth. The high, often around 1 values of ΔpH indicate that in these soils the acidification tendency is important. Former measurements in dolines on Bükk Plateau and Aggtelek Karst also showed this tendency of acidification in the soils (*BÁRÁNY-KEVEI, I. 1987 b*).

The pH and carbonate content is in connection with the limestone fragment content of the soil. According to the fragment content the soils can be divided into two groups. The soils mixed with limestone fragments have higher pH, lower ΔpH values and the pH increase downwards in the soil profile to a higher degree than that in the case of soils which not mixed with limestone fragments. The latter soils have no carbonate content at all, the pH is lower and the ΔpH values are high.

There were measurements in some dolines of the Bükk Plateau (*BÁRÁNY, I. 1980, KEVEINÉ BÁRÁNY, I. 1985, 1987, BÁRÁNY-KEVEI, I. 1987 b*). The soil samples were from the different exposition of slopes and from the bottom of doline. The organic matter content of these soils varies between 2-19 %.

After my measurements I found that the organic matter content of the investigated soils is very high (*Table 1, 2, 3, 4*).

The organic matter content of soils is lower in the sample sites of Aggtelek Karst than of Bükk Plateau. The soils on Bükk Plateau retained more of its original character than on Aggtelek Karst, because the Bükk Plateau has been a protected area much longer than the other karstic region (*BÁRÁNY-KEVEI 1998*). Now the human impact is relatively small on Aggtelek Karst as well, but former the grazing, agricultural activity and forestry was common in this area. For this reason over a widespread area the soils are degraded. Nowadays the grazing is still present in this part of Aggtelek Karst. The higher degree of soil degradation since the greater importance of human activity on Aggtelek karst can cause a lower organic matter content in the soils. This must be connected also with the quantity of precipitation (Bükk Plateau: 800 mm, Aggtelek: 650-700 mm) and the height above the sea level (Bükk Plateau: 750-830 m, in the Aggtelek area: 310-480 m). These together cause that the decomposition of organic matter is slower on Bükk Plateau.

Aggtelek Karst	organic matter content (%)			
sample site	5-10 cm	10-20 cm	20-30 cm	30-40 cm
1. (oak)	15.1	23.0	10.9	7.3
4. (oak)	12.7	8.6	9.3	5.0
8. (oak)	19.3	20.9	17.2	8.2
9. (oak)	72.6	50.0	75.2	34.1
11. (oak)	43.1	44.3	21.5	10.2
12. (oak)	29.7	16.8	18.2	10.0
13. (oak)	33.0	27.3	17.1	8.1
14. (oak)	18.0	18.7	16.2	14.9
16. (oak)	44.0	17.8	15.8	11.1
7. (pine)	15.8	13.1	12.3	5.1
3. (field)	12.6	9.4		
5. (field)	26.6	13.4	14.7	5.9
6. (field)	28.0	22.2	26.0	7.7
10. (field)	77.8	44.8	50.5	34.9
15. (field)	32.3	19.2	15.4	17.5
2. (stubble)	16.3	11.3	13.5	6.8

Table 1 The organic matter content of the soils on Aggtelek Karst

Aggtelek Karst	position	organic matter content (%)			
sample site	on the slope	5-10 cm	10-20 cm	20-30 cm	30-40 cm
19. (oak)	top	21.2	11.6	10.5	
18. (oak)	middle	16.8	11.4	14.6	9.5
17. (oak)	bottom	33.8	14.7	12.0	12.3
20. (oak)	top	26.6	18.3	16.4	
21. (mixed beech)	middle	22.4	19.3	10.2	12.2
22. (mixed beech)	bottom	24.1	12.9	10.3	12.5

Table 2 The organic matter content of the soils on Aggtelek karst, along 2 slopes

Bükk Plateau	organic matter content (%)			
sample site	5-10 cm	10-20 cm	20-30 cm	30-40 cm
2. (beech)	16.2	14.9	16.3	6.7
3. (beech)	very high	very high	very high	very high
9. (beech)	37.5	29.9	34.3	18
10. (beech)	34.9	32	20.3	15.6
15. (beech)	76.5	66.5	32.5	
5. (pine)	25.6	28.4	21.7	14.5
7. (pine)	39.6	31.3	22.6	11.8
8. (pine)	17.5	15.6	21.3	8
1. (mixed beech)	39.1	22.6	16	10.1
12. (mixed beech)	88.6	56.6	42.1	31.3
13. (seedling nursary)	55.4	49.5	39.6	24.1
4. (field)	34.9	37.1	28.6	15
6. (field)	19.6	19.5	14.3	12.2
11. (field)	55.4	37.9	46.4	12
14. (field)	29.5	22.4	20.6	13.6
16. (field)	38.2	31.7	17	7.9

Table 3 The organic matter content of the soils on Bükk Plateau

Bükk Plateau	position	organic matter content (%)			
sample site	on the slope	5-10 cm	10-20 cm	20-30 cm	30-40 cm
20. (beech)	top	very high	75.4	56.2	
19. (beech)	middle	36.6	25.9	20.7	16.1
18. (beech)	middle	36.5	28.6	36.8	
17. (beech)	bottom	38.7	31.6	17.0	18.1
21. (beech)	top	81.5	52.6	42.3	45.8
22. (beech)	middle	35.0	18.1	19.6	16.7
23. (beech)	bottom	25.9	19.7	23.1	18.7
24. (pine)	top	48.5	28.1	23.9	19.2
25. (pine)	middle	39.8	25.7	28.9	21.0
26. (pine)	bottom	66.4	46.4	31.6	15.4

Table 4 The organic matter content of the soils on Bükk Plateau, along 3 slopes

Soils of open fields

We collected soil samples on Bükk Plateau (sample sites 4., 6., 11., 14., 16.) and on Aggtelek Karst (sample sites 3., 5., 6., 10., 15.) as well. The soils of open fields on Bükk Plateau have a little bit lower pH than the soils of open fields on Aggtelek Karst. We can find acid soils on Bükk Plateau in a greater ratio (35 %) than on Aggtelek Karst (11 %). The ratio of weakly acid soils is nearly equal in both areas (55 %). The ratio of neutral and weakly basic soils is greater on Aggtelek Karst (33 %) than on Bükk Plateau (10 %). The pH of the soils on Bükk Plateau is lower both in the case of soils mixed and not mixed with limestone fragments. This must be connected with the quantity of precipitation (Bükk Plateau: 800 mm, Aggtelek: 650-700 mm) and the height above the sea level (Bükk Plateau: 750-830 m, in the Aggtelek area: 310-480 m).

The soil reaction of the stubble (Aggtelek Karst 2. sample site) is weakly basic (pH=7,6-7,9), the ΔpH values are low and the soil has more carbonate content than the soils mixed with limestone fragments in the open fields. This difference is caused by the agricultural cultivation.

The organic matter content of the soils of fields is very variable, just as in the case of forests (*Table 1 & 3*). The soils of fields on Bükk Plateau have a bit higher organic matter content than the soils of fields on Aggtelek Karst. This is in connection with the height above sea level, the precipitation and the human activity, as I have mentioned it before. In the investigated part of Aggtelek Karst the grasing is still present on the fields (in the 5., 6., 15. sample sites it is surely present), so here the supply of dead plants may be smaller. There is only one part on Bükk Plateau where grazing is allowed: on the Nagymező ("Great Field") where the famous stud lives. The 16. sample site takes place on this field. The lower part of this soil has less organic matter content than the soils of fields in general have in this depth. The soil of stubble (Aggtelek Karst 2. sample sites) has low organic matter content compared to the fields since the reduced supply caused by harvesting. The samples were collected from flat areas (16. (Bükk) and 2., 5., 15. (Aggtelek)), from the edge of dolines (4., 6. (Bükk) and 6. (Aggtelek)) and from gentle slopes (3., 10. (Aggtelek)). One sample site (11. Bükk) was on the bottom of a doline.

Soils of beech forests

We collected soil samples in beech forests only on Bükk Plateau (subject to the plant conditions). The weakly acid (31 %) and acid soils (24 %) dominate. There is no strongly acid soil. Neutral and weakly basic the 45 % of the soils.

The soils in beech forests are mixed with limestone fragments and according to this they have some carbonate content (usually below 1 %). The reaction of soils is neutral in the deeper layers. Closer to the surface the pH is lower. The ΔpH values are commonly not too high. There are two exceptions in the soils: in the 17. sample site the soil has no limestone fragments, so the soil reaction is lower, the ΔpH values are high and there is no carbonate content in the soil. There is a high amount of fragments in the 2. sample site, still the carbonate content is 0 %, the pH is acid (pH=4,6-5,5), and the ΔpH values are high.

The organic matter contents of the soils in beech forests are very high. In the upper layer they are usually above 30 %. But in the 30-40 cm soil layer the organic matter content is still high (*Table 3 & 4.*). The sample sites are on the bottom of slopes (2., 3., 9., 17., 23.), on the middle part of slopes (10.,15., 18., 19., 22.) and on the top of slopes (20., 21.). The 20-19-18-17. samples were collected on the same slope profile. Similarly, the 21-22-23. samples aim at comparing the characteristics of the soil along one slope. The comparison of these latter samples does not show the expected results, namely, that the soil of the bottom part of the slope has lower organic matter content because of the soil degradation. Moreover, in this case the opposite is true. This slope undulates gently, the angle of slope is only 4-5°. According to the results the erosion must be minimal. The 20-19-18-17. sample sites are on a steeper slope (the angle of slope is 9-10°). The highest – extreme high - organic matter content was measured on the top of this slope. (Here the soil is a very loose black rendzina.) There is no considerable change in the organic matter content along this slope – except the mentioned soil on the top.

Soils of oak forests

According to the plant conditions we collected soil samples in oak forests only on Aggtelek Karst. Almost the half of the examined soils are strongly acid and acid. 22 % of the soils are weakly acid, neutral and weakly basic are 32 %. We can establish that the soils in oak forests on Aggtelek Karst have lower soil reaction than the soils in beech forests on Bükk Plateau. This difference may be caused – besides by the difference in the plant-cover - by the difference in the mixing of limestone fragments. There are only 5 sample sites on Aggtelek Karst where the limestone fragments appear in the soil and in 8 sample sites the soil is not mixed with limestone fragments. But there is only 1 sample site on Bükk Plateau where the soil is not mixed with limestone fragments and in the other 12 sample sites the limestone fragments appear in the soil. (The soils on Bükk Plateau are generally thinner than the soils on Aggtelek Karst.)

The organic matter content in the soils of oak forests is lower than in the soils of beech forests, mixed beech and pine forests (*Table 1 & 2.*). There are only 5 samples of the 13 where the organic matter content of the 5-10 cm layer is above 30 %. The lower values are valid in the case of the lower layer of the soils as well.

The sample sites are on a flat area (1.), on the bottom of slopes (4., 17.), on the middle part of slopes (11., 12., 16., 18.), on the top of slopes (9., 13., 19., 20.) and in dolines (8., 14.). The 19-18-17. samples are along the same slope. The angle of slope is 9-10°. The organic matter content of soil is enriched on the bottom of the slope. This can be a proof of the redeposition of soil by erosion. The samples collected on the bottom of dolines show no enrichment of organic matter compared to the other soils in oak forests.

Soils of pine forests

I examined six soils from pine forests on the Bükk Plateau (samples 5., 7., 8., 24., 25., 26) and one (sample site 7.) on Aggtelek Karst. The pH of the soil in the pine forest on Aggtelek Karst is lower (pH= 5,0-5,3) than in the pine forests on Bükk Plateau. The pH does not increase significantly downwards in the soil profile while in the case of the pine forests Bükk Plateau the increase of the pH can be 2 units. In this soils the weakly acid (46 %) and acid (21 %) reactions dominate, but there are neutral (8 %) and weakly basic (25 %) soils as well. The limestone fragments appear in some sample sites (5., 24., 25., 26.).

The pH of soil in the seedling nursery (Bükk, 13. sample site) is weakly acid and neutral (pH=6-7), the ΔpH values are low (ΔpH=0,6-0,5). This must be connected with the chemical fertilization in this place and the high fragment content of the soil.

Just as the pH, the organic matter content of the soil in the pine forest on Aggtelek Karst is lower than in the pine forests of Bükk Plateau (*Table 1, 3 &4*). The samples were collected on the bottom of slopes (5., 7., 7. (Aggtelek), 26.), on the middle part of slope (25.) and on the top of slope (24.). The 8. sample came from the bottom of a doline. The 24-25-26. samples are along the same slope. The angle of slope is 15-16°. The enrichment of organic matter is observable on the bottom of the slope. It is interesting that the soil in the bottom of a doline has the lowest organic matter content – but still rather high – compare to the other soils in pine forest. In the seedling nursery the soil was collected on the edge of a doline. The organic matter content is high in the lower layer of soil as well. The lowest organic matter content in the soils of pine forests was measured in the soil of the pine forest on Aggtelek Karst.

Soils of mixed beech forests

The 1. and 12. sample sites on Bükk Plateau are in beech mixed with pine forest, while the 21. and 22. sample sites on Aggtelek Karst are in beech mixed with oak and hornbeam. There is no limestone fragment in the soils on Aggtelek Karst. In the case of the mixed beech on Bükk Plateau the limestone fragments appear in the soils. In spite of this, the soils of the mixed forests on Aggtelek Karst have higher pH (88 % weakly acid and 12 % acid) than on Bükk Plateau (25 % strongly acid, 38 % acid, 25 % weakly acid and 12 % neutral). This may be caused by the difference in the plants (oak and hornbeam against pine) and the higher quantity of precipitation on the Bükk Plateau.

The sample sites are on a flat surface (1. Bükk), on the bottom of a slope (22. Aggtelek) and on the middle part of a slope (21. Aggtelek and 12. Bükk). The 21-22. sample sites are along the same slope. On the top of this slope the sample was collected in an oak forest (22. Aggtelek). The angle of slope is 15-16°. The redeposition of soil is not proved by considering the organic matter content of the soils. Although the organic matter content on the bottom of the slope is a little bit higher than on the middle part of the slope (*Table 2*)

Conclusion

In my essay I studied the soil reaction, carbonate and organic matter content of different plant-covered areas in the karstic region of Bükk Plateau and Aggtelek Karst. Although the characteristics of the bedrock point towards the fact that these soils have high carbonate content and neutral soil reaction, this is not completely justifiable. The carbonate contents are mostly below 1%. The soil reaction is dominantly acid and weakly acid, only 1/3 part of them is neutral and weakly basic. The often high, around 1 values of ΔpH warn us of the acidification tendency of these soils.

The pH and carbonate content is in connection with the limestone fragment content of the soil. The soils mixed with limestone fragments have higher pH, lower ΔpH values and the pH increase downwards in the soil profile to a higher degree than that in the case of soils which not mixed with limestone fragments. The latter soils have no carbonate content at all.

The soils of beech forests on Bükk Plateau averagely have higher pH values than the soils of oak forests on Aggtelek Karst. This is caused not only by the difference of plant covering but by the difference of fragments supply as well. The soils of fields on Bükk Plateau are more acid than the soils of fields on Aggtelek Karst. This can be mainly because the Bükk Plateau is higher above sea level and has more precipitation than the Aggtelek Karst.

The organic matter content of these soils is very high. There is no direct connection between pH and organic matter content. The redeposition of soil on the slopes is not proved on the basis of the change of organic matter content of the soils. There were only 2 of the investigated 5 slope profiles where the results show the enrichment of organic matter on the bottom of slopes. The soils of open fields have the lowest organic matter content. Of the forests the beech forests have the highest organic matter content in the soil. In general the soils of Bükk Plateau have higher organic matter content than the soils of Aggtelek Karst. This can be because the higher amount of precipitation and the cooler weather hinder the decomposition of organic matter. The other reason is that the human impact has been stronger on the Aggtelek area so the degradation of soils is stronger.

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WEATHER EVENTS DURING THE FIRST TARTAR INVASION IN HUNGARY (1241-42)

Kiss, Andrea

Summary

On the basis of 29 sources, including 41 direct and indirect data, an attempt is made to collect and analyse the available, contemporary sources, related to events during the first Tartar invasion of Hungary in 1241-42. Most of the collected, direct information is strongly connected to the severe, long-lasting frost of January 1241 when the Danube froze over in the section flowing within the territory of Hungary.

Sources and conditions

In the 13th century, the first Tartar invasion (1241-42) gained great "publicity" not only in Hungary, but also in many parts of Europe. According to the medieval narrative sources that remain to us, for Europe, the first Tartar invasion became the best known event of the 13th century concerning Hungary. Moreover, not only many foreign sources, but also an unusually large number of preserved contemporary Hungarian sources report on events during the Tartar invasion. Some weather events at this time - directly or indirectly - were also included in these narratives. These sources are especially important as they provide quite precise information on the unusually cold weather conditions during some parts of the winter of 1241-1242. Some recent research on general winter conditions in Western Europe (mainly including sources from Switzerland, Germany, and partly the Czech Lands, present Slovakia, Poland and Hungary) partly overlapping with this same period suggests that the winters of the 1240s were generally not below the average (*Pfister et al.*, 1998, 548.). On the other hand, according to Glaser and his colleagues, the winter temperature index of the 1240s was below (-2) the average (*Glaser et al.*, 1999, 26.).

In this short study, the data from 33, mainly contemporary sources, were considered: while 10 of them are Hungarian or Dalmatian, containing most of the direct weather information, 23 are foreign, Western- and Central-European sources, mainly containing indirect information. Of the 41 data, 24 speak of hunger in Hungary during and after the Tartar invasion. Seven are connected to the attacks themselves and invasion of animals such as wolf, fox, eagle and locust at about the same time. Although only 7 (together with 3 other connected data) of the sources refer to direct weather events such as winter frost, frozen rivers (mainly the Danube), melting swamps and early spring frosts, many of these indirect sources also reflect not only on the effects of the disastrous invasion but to some extent on the previous unfavourable weather conditions (*Fig. 1*).

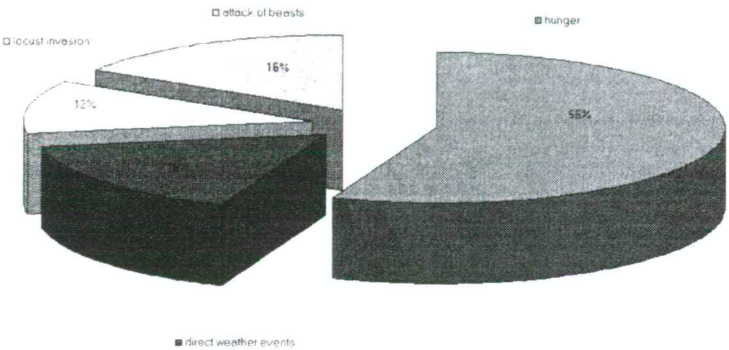

Figure 1 Distribution of the available sources referring to the first Tartar invasion of Hungary (1241-42)

Information content and its interpretation

This collection of sources contains at least five types of information which can be analysed from a climate historical point of view:

1) Only one source, Rogerius (archdeacon of Várad at that time - today it is Oradea in Romania) mentions in the *Carmen miserable* (written around 1243) the heat in the Hungarian camp during the battle of Muhi, on the 11th of April by the Sajó river (Rogerius. *Szentpétery* Vol. 2., 1937, 570.). As there are no details in the source giving a reason for this heat - whether it resulted from the great number of warriors within a small area or because of weather conditions – firm conclusion on the prevailing weather conditions cannot be drawn. However, the swamps by the Sajó river were impassable in those days. (The only possible ford for crossing the river was to find the bridge north of the scene of the battle.)

2) An unusual event is noted in five contemporary, reliable sources: the Danube was deeply frozen, in Hungary during a certain period in the winter of 1241-42 (Rogerius. *Szentpétery* Vol. 2., 1937, 583-584.; Thomas Spalatensis. MGH SS. 29/590.; *Györffy*, 1987a, 179.; etc.). According to Rogerius, such an event has not happened here for long time ("*Ecce, in hyeme nivis et glaciei habundantia supervenit ita, quod Danubius, quod non acciderat a multis retroactis temporibus, gelabatur*"). This opinion - concerning e.g. the 1230s - can be supported with the above-mentioned winter reconstruction referring to Central Europe (*Pfister et al.*, 1998, 548.; *Glaser et al.*, 1999, 26.). Rogerius also mentions the abundance of snow and ice in the same winter. (Rogerius. *Szentpétery* Vol. 2., 1937, 583.) The ice-cover of the Danube was so thick that it could hold herds of animals, and what is more, the Tartar army as well (Rogerius. *Szentpétery* Vol. 2., 1937, 584.). This could happen only if it was preceded by long-lasting, permanent frost in large sections along the Danube. Additionally, Thomas of Spalato (archdeacon) mentioned that river waters froze everywhere, which may also support the idea that strong frosts prevailed in the Carpathian Basin during this period (Thomas Spalatiensis. MGH SS. 29/592.).

In connection with the freezing-over of the Danube, it is known that some days before the Tartars crossed the river, Hungarians were skirmishing with the Tartar warriors every day. The Hungarians broke up the ice on the Danube every day: the ice-cover of the river was already quite strong in some places many days before the Tartar crossing, and the river would have been frozen much earlier if Hungarians had not frequently broken up the ice (Rogerius. *Szentpétery* Vol. 2., 1937, 583.). However, according an Austrian letter – written by Felix, the abbot of Schottenstift in Vienna (4th January, 1242) – the river would have been frozen already from Christmas (*Györffy*, 1987a, 394.). Although his information was most probably wrong as – according to other, reliable sources - Tartars did not cross the river until late January, the idea of the frozen river is perhaps based on his own experience in Vienna.

Even more exact information appears in two letters asking for help, written by Hungarians to the pope. In the first letter, written by Béla IV on the 19th of January, it is noted that the Tartars have not yet crossed the river (*Marsina*, 1987, 72.; *Szentpétery*, 1923, 214.). The second letter, written on the 2nd of February, reports that Tartars had already crossed the frozen Danube and begun the invasion of the northwestern parts of the Transdanubian region (*Györffy*, 1991, 87., *Marsina*, 1987, 74.). Presumably, the crossing took place near Buda (*„portus Danubii"*) (*Györffy*, 1991, 87.). However, Tartars probably also crossed the Danube around Esztergom as well.

After crossing the Danube, Tartars attacked Óbuda and Esztergom (without success) and then, probably soon after the 2nd of February, (Székes)Fehérvár. However, by the time of the Tartar attack, the swamps around the island of Fehérvár began to melting suddenly (Rogerius. *Szentpétery* Vol. 2., 1937, 585.).

This rapid melt may have been one reason, among a number of other circumstances that while the *civitas Latinorum* at the edge of the swamp, on the mainland, could be occupied and destroyed easily, Tartars were not able to capture the fortified island surrounded by swamps (*Fig. 2*) (Thomas Spalatiensis. MGH SS. 29/593.). Although the thawing of the swamp is mentioned only by Rogerius, the other source for these events, Thomas of Spalato, does not write about this explicitly but he does accept that the swamp around the island played a significant role in the defense. As the swamp could only have protected the island if it was impassable (so not deeply frozen), this description indirectly supports Rogerius' report.

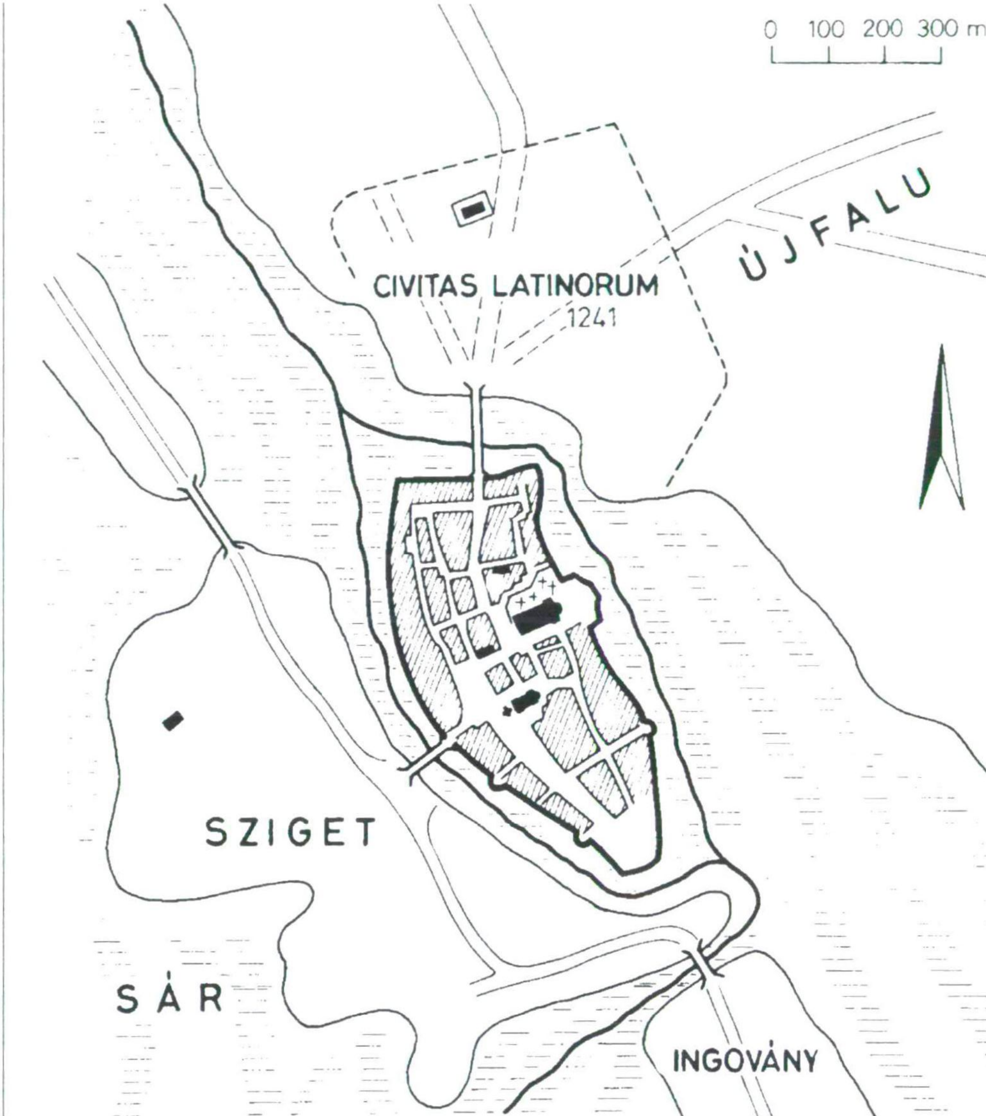

Figure 2 Reconstructed location of the mid-thirteenth-century Fehérvár: the fortified Island and the Civitas Latinorum (*Györffy, 1987b, 378.*) (Local geographic names: Újfalu, Sziget, Sár, Ingovány)

In conformity with the above description of the events, it can be presumed that though the beginning of the severe, long-lasting frost is uncertain, it must have begun at least in the first half of January and lasted until the end of January - beginning of February. These data are also significant since - concerning the winter in Europe - there are only very limited number of direct sources available for the winter of 1241-1242 (see *Alexandre*, 1987, 389-390.).

3) According to Thomas of Spalato, Caydan (the Tartar prince) could chase the king – who had escaped from Hungary to the Dalmatian island of Trau (today Trogir in Croatia) – in the direction of Spalato (today Split in Croatia) with only part of his army because the severe frosts of early March meant there was not enough grass for the horses (Thomas Spalatiensis. MGH SS. 29/594.).

In spite of the fact that the last part of their journey led through Slavonia and Croatia (to Dalmatia), this observation may reflect to some extent the contemporary weather conditions in certain parts of the Transdanubian region as well. The length of the period of frost in March cannot be measured. It is only known that the Tartars returned to Inner Asia in spring of 1242 (which also means that they had to cross the Danube again) (*Kristó*, 1988, 131.).

4) The most numerous group, among the sources referring to the first Tartar invasion of Hungary, includes 24 mentions of the great hunger during and after the long year of war. This famine was known and reported on in Europe as much as the Tartar invasion itself. In fact, in most sources it was mentioned together with the invasion, sometimes with the comment that this famine, in the unstable period of 1242 and 1243, resulted even greater decline of population than the Tartars (Continuatio Sancrucensis II. MGH SS. 9/641.; Anonymi Chronicon Austriacarum. *Rauch*, 1793, 245.; etc.). This was also mentioned by most of the Hungarian chronicles (*Szentpétery* Vol. 1., 1937.). Some connecting details of the possible effects were discussed by Györffy (*Györffy*, 1987a, 29.).

The Tartar invasion was very much responsible for the hunger since at least two sowings and one harvest were missed in the areas east of the Danube while Tartars took or destroyed all of the reserved seeds as well as the harvest. On the other hand, these difficulties may also have been related to more than one unusually cold month of the previous winter, and perhaps the frosty weather of October in 1242, which was described for Austria, could also affect Hungary (Continuatio Sancrucensis. MGH SS. 9/640., see also *Brázdil and Kotyza*, 1995, 102.). There is a probability that these long-lasting frosts did not spare the yields either. Even if Rogerius mentions in his work that there was extremely cold weather with a lot of ice and much snow, snow presumably could not entirely protect the soil and the vegetation against the negative effects of severe frost over such a long period. Moreover, although significant parts of the livestock might have been driven away by the Tartars or simply left to wander about on their own, if we accept that there was deep snow and frost, the remaining domestic animals would have also suffered from the consequence of the vicissitudinous winter.

5) Other unusual circumstances are also mentioned in connection to the afore-mentioned famine. There were frequent attacks by wolf-packs (in some sources foxes and eagles are also mentioned) against humans. In some cases beasts ran into houses, attacking and eating people (Thomas Spalatiensis. MGH SS. 29/595.; Continuatio Sancrucensis. MGH SS. 9/641.; Annales Polonorum. MGH SS. 19/634., 635.; Rocznik Traski. MPH 2/838.; Rocznik Małopolski. MPH 3/167.; etc.). These descriptions may also provide indirect evidence of severe winter conditions, since such animals attack people only if their ordinary food, namely herbivores, decreased sharply in numbers, in most cases because of a very snowy (or/and frosty) winter or very dry period effecting the vegetation. In addition, according to partly the same, partly other, primarily Austrian sources (two of which were copies), locusts also appeared in great quantities, at the time (or immediately after) the famine (Anonymi

Chronicon Austriacarum. *Rauch*, 1793, 245.; Continuatio Sancrucensis. MGH SS. 9/641.; etc.).

Possible later parallels: was it an extreme winter?

In the 20^{th} century (1901/1956), ice floe appears at an average heat sum of –13.7 °C, and massive ice cover develops at an average heat sum of –98.9 °C on the Danube at Budapest (*Horváth*, 1979, 46.). Ice can appear at Budapest (in an optimal case) at an average winter temperature of 3 °C or less, and standing ice-cover can develop at 1.4 °C or lover average winter temperature (*Horváth*, 1979, 50.). However, the appearance and extension of ice-cover also very much depend on the temperature conditions in the upper catchment area of the river. Before the regulation works, the river had a much wider bed at Buda as well as at Pest, therefore, ice floe could start earlier than today. As an effect of the regulation works, the average duration of massive (standing) ice-cover fell dramatically, from 20 days to 8.2 days (in case of approximately the same winter temperature conditions). While the annual frequency of the appearance of standing ice-cover in winter was 68% in the 19^{th} century (1819/20-1889/90), it descended to 43% by the first half of the 20^{th} century (1900/01-1955/56) (*Horváth*, 1979, 60.). These differences, most probably, can be connected both to regulation works with the growing pollution of the river as well as to the changes in climatic conditions.

Applying the available historical sources of the Réthly collection, referring to the weltering and freezing over of the Danube, the best documented area in the Carpathian Basin is the present Bratislava (H-Pozsony, G-Pressburg) in Slovakia, but a considerable number of sources is available for Buda (with Pest) as well. On the basis of the data found mainly in the early newspapers of the second half of the 18^{th} century, we can say that – similarly to the first half of the 20^{th} century (1900/01-1955/56) – there was almost no year without at least the weltering of the Danube. In case of several winters in the second half of the 18^{th} century, not only weltering, but also massive ice cover developed on the Danube at Buda (e.g. in 1747, 1781, 1784-1789, 1792, 1793, 1795) on which heavied wagons could cross. (Réthly, 1962.) However, in the late 19^{th} century and at the beginning of the 20^{th} century, significant changes occurred in the water-course of the Danube and its tributaries, which – together with growing pollution – could significantly influence the freezing conditions of the river.

As it has been already mentioned, in the second half of the 18^{th} century the appearance of massive ice cover on the river was not especially unusual. On the basis of the available contemporary sources neither the duration of the massive ice cover on the river, nor the severity of the winter of 1241/42 can be estimated. Nevertheless, the existence of massive ice cover can be connected to colder than average temperature conditions, compared to later sources and the present situation.

Conclusions

In accordance with the relatively large amount of contemporary and almost contemporary sources, some conclusions can be drawn related to the weather conditions at the time of the first Tartar invasion in Hungary. On the basis of the sources (describing the freezing over of the Danube and attacks by wild beasts among other events) used in this study we can presume that the winter – or at least a certain part of the winter of 1241-42 was unusually cold over great parts of Hungary. Moreover, there is also a probability – based on only one reliable source - that the first part of March may have been colder than usual, not only by the Dalmatian coast (Spalato/Split), but perhaps in Slavonia and in the southwestern part of Hungary as well.

These proposed conclusions concerning weather conditions during the winter of this year in other parts of Europe differ from results of other studies from outside Hungary. The unfavorable weather conditions together with the Tartar invasion had disastrous direct and indirect consequences on the country. However, this was also followed by other, partly or entirely independent effects (e.g. a locust invasion) discussed in the article. Additionally, these data show that the widely extended view that all problems in following years were the result of the Tartar invasion is a bit over-simplified. On the other hand, it seems clear that no complete reconstruction of the winter conditions of 1241-42 can be carried out using the available contemporary sources alone. Therefore, in order to have more precise information, the application of the future results of other fields e.g. archeological, natural scientific research will be of crucial importance in testing the hypotheses developed in this study.

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